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JUN 22 1938

THE JUNE SCIENTIFIC MONTHLY

EDITED BY J. MCKEEN CATTELL

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The author has prepared for the layman the story of the genesis of the scientific theories on which the structure of human knowledge is based. He includes accounts of the lives of the scientific men, who developed these theories—Copernicus, Hutton, Dalton, Lavoisier, Rumford, Huygens, Malthus, Schwann, Darwin, Marx, Pasteur, Freud, Chamberlin, Boas and Einstein.

Charles Darwin: A Portrait. GEOFFREY WEST. xiv + 359 pp. $3.50. Yale University Press.

The story of the life of a man who has profoundly affected the thinking of the modern world. It is more than a nineteenth century story, beginning in the eighteenth century with Darwin's grandfathers as young men. This is the twenty-fifth work published by the Yale University Press on The Philip Hamilton McMillan Memorial Publication Fund.

Forest Pathology. JOHN SHAW BOYCE. 600 pp. 224 illustrations. $5.00. McGraw-Hill.

This volume will serve both as a text and reference book. It covers the important species of forest trees in the United States and Canada, with especial emphasis upon identification, tree habits, silvical data, and tree ranges. There are many photographs illustrating the distinguishing features of leaves, flowers, fruits, seeds, twigs, bark, and the habits of trees.

Physiography of Eastern United States. NEVIN M. FENNEMAN. xiii + 691 pp. $6.50. McGraw Hill.

In this book the atmosphere and ocean are mentioned only as relating to the land surface. The data discussed are in large measure the product of geological investigations. The author has aimed to organize, rather than to assemble this data, to establish order, rather than to describe the United States.

Giant Fishes, Whales and Dolphins. J. R. NORMAN and F. C. FRASER. xiii + 361 pp. $4.00. Norton.

This book provides simple key descriptions and accurate illustrations and gives a readable account of the appearance, size, habitat, mode of life, food, breeding habits and economic importance of the various specimens that find a place in the book. The illustrations, consist of eight colored plates and more than one hundred drawings by Col. Tenison.

Journey to Manaos. EARL PARKER HANSON. 342 pp. $3.00. Reynal and Hitchcock.

This is a narrative of an expedition sent out by the Carnegie Institution of Washington to measure the "declination" of the earth's magnetic field and the difference between true north and the magnetic north which controls the compass, etc. These measurements were repeated at some eighty stations where observations had been made earlier by other investigators.

Van Nostrand's Scientific Encyclopedia. 1234 pp. $10.00. Van Nostrand.

A single volume encyclopedia which covers the basic sciences, the applied sciences of navigation, aeronautics and medicine and the three branches of engineering—civil, mechanical and electrical. Over ten thousand terms are given and there is an extensive system of cross-indexing.

Index Generalis, 1938. English edition. S. DE MONTESSUS DE BALLORE. 2614 pp. $12.50. Crofts.

An index, published annually, which outlines the principal intellectual resources of the world. It includes institutions of higher learning, libraries, observatories, scientific institutions and learned societies.

An Ecological Glossary. J. RICHARD CARPENTER. viii + 306 pp. $4.00. University of Oklahoma Press.

This is the first glossary that has appeared since the formulation of the biotic community concept. There is an introduction outlining the development of ecological nomenclature with a bibliography of the more important papers dealing with terms and concepts.

THE SCIENTIFIC MONTHLY

JUNE, 1938

UTILITARIAN ASPECTS OF GEOPHYSICS

By A. G. McNISH

DEPARTMENT OF TERRESTRIAL MAGNETISM, CARNEGIE INSTITUTION OF WASHINGTON

THE last few years have witnessed the rapid growth and integration of a distinct branch of science dedicated to investigating the physical properties and processes of the earth. In addition to its purely intellectual fascination this new geophysical science is proving of intense practical importance to our present-day civilization. The geophysicist may point with pride to past and present services of his science and, if permitted a little speculation, may forecast even greater services in the future.

The ways in which geophysics may be of service can be classified in three categories: First, direction toward a more economical exploitation of natural resources; second, prediction of natural phenomena and recommendation as to the most effective means of avoiding or taking advantage of their effects; and third, actual methods of avoiding unfavorable occurrences and causing favorable ones, which, speculative as it may seem, are not outside the bounds of possibility. That man may some day be master of the earth and not merely an animal living upon it depends upon the extent to which we avail ourselves of the scientific knowledge which we have and can acquire. A brief discussion of the value of geophysics may be presented more clearly by considering each department of the science separately.

METEOROLOGY

No one who has experienced the vicissitudes of weather can fail to recognize the importance of meteorological forecasts. That the "weather man" has sometimes erred in no way argues against the utilitarian character of his predictions. During past years his prognostications have been based upon meager information derived largely from the thin layer of air in which we move, close to the earth's surface. Thus, the meteorologist has had to content himself with a two-dimensional picture to solve what is actually a three-dimensional problem.

But to-day flights by airplane at a few scattered stations supply data taken along the third dimension at various heights in the atmosphere. Fragmentary as they are, these bits of information reveal a more comprehensive picture of the processes which have and are about to occur, of the nature of various air-masses, their origin and motion. The present trend in the science is toward the acquisition of more complete and detailed information concerning the higher layers of the atmosphere upon which so much of our weather depends. When these facts have been acquired and correlated a more satisfactory method of forecasting will follow with attendant benefits to society. This new information will be brought to us by radio-meteorographs

Photo by courtesy United States Weather Bureau.

RADIOMETEOROGRAPH ATTACHED TO PARACHUTE AND SOUNDING BALLOON

MECHANICAL WEATHER-OBSERVERS ARE SENT TO GREAT HEIGHTS IN THE ATMOSPHERE IN FAIR WEATHER OR STORM WHENCE THEY REPORT BY RADIO THE CONDITION OF THE AIR AT VARIOUS HEIGHTS. THIS NEW, IMPROVED MEANS FOR OBTAINING REGULAR METEOROLOGICAL DATA IS OF GREAT ASSISTANCE TO THE FORECASTER.

carried to great heights by small balloons. Expensive flights by airplane, which are not possible in bad weather when they are needed most, will no longer be necessary. Instead robot weather-observers will be carried aloft and send back radio signals describing atmospheric conditions at various heights.

The possibility of forecasting weather for entire seasons has received much attention from meteorologists. Vast amounts of data are being accumulated to ascertain if such forecasts are possible and to guide in making them if they are. The St. Swithin's Day myth and other superstitions regarding weather were blasted long ago by scientific investigations. Instead, some investigators are looking to variations in solar radiation and sunspots for indications of weather, but without success. Ocean-currents, ice-fields and snow-cover, and associations of

weather in one part of the world with subsequent weather in another part have all been studied with the view of long-range forecasting. The value of reliable seasonable forecasts to farmers, merchants and industrialists is self-evident. Meanwhile, the search goes on.

Beyond the immediate scope of forecasting weather is the study of climate, which is only the weather on a large scale. Other branches of geophysics show that great climatic changes have occurred in past ages. Since change itself is the only constant thing on this earth, our climates must be changing even now, perhaps too slowly to be noticed, perhaps not. The terrific dust-storms to which this country has been subjected during recent years may be but temporary; on the other hand, they may be forerunners of a complete change in climate which may transform the central part of our country into a vast desert. A more far-sighted national policy in the past and more thoughtful exploitation of the soil in the light of present climatological knowledge would have mitigated the severity of these plagues of dust. It is of utmost importance to ascertain the real geophysical facts involved.

Hydrology

It was no provision of nature which placed a river near almost every large city. The importance of water-systems to civilization has been recognized by every historian. Not only do waterways provide ready means of cheap transportation, but they likewise perform the twofold service of bringing water to our cities and of carrying away filth which otherwise would infect the inhabitants. Artificial irrigation has been man's method of combating an arid climate—one of his supreme conquests of nature. Modern civilization goes even further and harnesses the power of rivers and transforms it into electric power. Since most of the water which runs in rivers seeps through the soil, the study of ground-water is important. Although man has not as yet learned to control the rain which falls upon the earth, he has learned how to make the most economical use of that which does fall. He has learned that forests are necessary to prevent the rain from rushing too madly to the sea and he has learned that certain types of plants permit the rain to penetrate deeper into the soil than others. Application of some of this knowledge might have done much toward diminishing ravages of the drought which has recently laid waste to large areas of our land.

While rivers perform great services to man, sometimes their devastations outweigh their services. Periodic floods have won for the Yellow River the opprobrious epithet "China's sorrow." Floods, however, are not beyond control. While we can not control the amount of water which falls into a river-basin, the science of hydrology teaches us the most effective ways of keeping a river within its banks, and failing this at least makes predictions as to the imminence and magnitude of flood-dangers. In a few notable cases, by means of dams and reservoirs, the amount of water flowing through a river has been brought under almost complete control.

Of greater importance than the threat against man's creations during floods is the vaster danger which threatens the economy of entire regions, namely, abnormal soil-erosion. Under natural conditions, erosion is usually a gradual process, but with cultivation of the land the quantities of material carried away by floods are principally topsoil, the very basis of successful agriculture, which nature has required centuries to produce and which man may never adequately restore by artificial means. The prevention of these ravages which have already laid waste to large areas of our land is one of the many services the science of hydrology is capable of performing.

Photo by courtesy United States Bureau of Reclamation.

BOULDER DAM AND LAKE MEAD

STEMMING THE MIGHTY COLORADO RIVER WHERE IT THREADS BLACK CANYON, BOULDER DAM RISES 726 FEET ABOVE BED ROCK AND CREATES LAKE MEAD, 40 MILES WIDE AND 115 MILES LONG, THE LARGEST ARTIFICIAL LAKE IN THE WORLD. AGRICULTURAL LANDS IN RICH IMPERIAL VALLEY WILL BE PROTECTED FROM FLOODS, AND PURCHASE A STEADY SUPPLY OF WATER FOR IRRIGATION. ETC.

Oceanography

Though man is primarily confined to the land surface of the earth, he can not be unmindful of the fact that three-fourths of the globe upon which he lives is covered by water. Though much of oceanography belongs to other branches of science, the physics of the ocean constitutes no small part of the subject. Oceans form the highways between nations; a proper knowledge of their tides and currents, of the topography of the oceanic floor, of marine meteorology and of the compass-directions at sea are essential to our maritime activities. The winds and currents of the oceans are important in affecting the drift of icebergs from the frozen polar seas to warmer regions. One needs only to think of the disaster which the name *Titanic* recalls to realize the importance of knowledge concerning the drift of icebergs on the open seas.

In addition to their service as highways of nations, the oceans perform valuable services to society in many other ways. Vast herds of living creatures graze in the natural meadows of the sea untended by cowboys or shepherds and supply the world with much of its supply of food. It is estimated that the output of ocean fisheries is nearly $1,000,000,000 annually. Preservation of these fisheries during the growth of a mechanized civilization is one of the problems faced by oceanographers. Since proximity to centers of civilization make a fishing-ground more valuable, it is essential that such grounds are not injured by pollution from cities and their industrial plants. Knowledge of tides and currents assists in efficient exploitation of the natural resources of the sea.

Like most natural benefactors, the ocean is frequently a great destroyer. Storms which do mild damage to inland cities visit greater fury upon those situated upon the sea-coast. Tremendous tides heaped up by gales and hurricanes and rendered more devastating by large waves which top them cause great damage to life and property. The predic-

Photo by courtesy United States Geological Survey.

FLOWING WELL IN ROSWELL ARTESIAN BASIN, NEW MEXICO

STUDY OF SUBTERRANEAN WATER-SUPPLIES ENABLED HYDROLOGISTS TO BRING THROUGH THIS GUSHING WELL DELIVERING 3,190 GALLONS OF WATER A MINUTE IN A LAND OF CREOSOTE BUSH AND MESQUITE GRASS. EFFICIENT, ECONOMICAL USE OF THESE NATURAL RESOURCES IS FOSTERED BY THE SCIENCE OF HYDROLOGY.

Photo by courtesy United States Bureau of Reclamation.

BOULDER DAM AND LAKE MEAD

STEMMING THE MIGHTY COLORADO RIVER WHERE IT THREADS BLACK CANYON, BOULDER DAM RISES 726 FEET ABOVE BED-ROCK AND CREATES LAKE MEAD, 40 MILES WIDE AND 115 MILES LONG, THE LARGEST ARTIFICIAL LAKE IN THE WORLD. AGRICULTURAL LANDS IN RICH IMPERIAL VALLEY WILL BE PROTECTED FROM FLOODS AND IT WILL HAVE AN ASSURED SUPPLY OF WATER FOR IRRIGATION. FUTURE POWER DEVELOPED AT THE DAM WILL BE USED IN PUMPING WATER TO HIGHER LANDS

Photo by courtesy United States Coast Guard.

COAST GUARD CUTTER ON NORTH ATLANTIC ICE-PATROL

PATROLLING THE SHIPPING LANES OF THE NORTH ATLANTIC ON INTERNATIONAL SERVICE OF ICE OBSERVATION, COAST GUARD CUTTERS CHART THE POSITIONS OF MENACING ICEBERGS FROM MARCH TO JULY. OBSERVATIONS OF WIND, CURRENTS AND CONDITION OF THE SEA-WATER AFFECTING DRIFT OF ICEBERGS ENABLE OCEANOGRAPHERS TO PREDICT THEIR FUTURE TRAVELS.

tion of such tides as well as the ponderous waves such as broke upon distant shores after the eruption of Krakatoa constitute one of the oceanographer's tasks.

Geodesy

The science of measuring the earth is older than the pyramids. Its importance is indisputable. Essentially it is the function of geodesy to determine within proper limits of accuracy the size and shape of the earth and to correlate points on its surface to best meet the requirements for mapping, engineering and science. The modern geodetic survey does more than determine latitudes, longitudes, elevations, lay out boundaries and locate points on which rights of property are based. Geodetic control and the maps based on it are of inestimable value to the engineer who would build roads, canals, bridges, dams and the countless features of man's exploitation of the earth's surface.

At first consideration the determination of the size and shape of the earth appears to be an academic problem, but it is of intense practical importance because the earth is far from spherical in form. Accurate mapping must take this lack of sphericity into account. In astronomical observations the figure of the earth must be allowed for because a plumb-line does not point directly toward the center of the earth at all places on its surface. Variations in gravitational force from place to place arise partly because of the departure of the earth from truly sperical form. This is strikingly revealed by variations in the rate of a clock controlled by a gravity-pendulum if it is carried to different parts of the earth.

Beyond this the geodesist is able to give us information of the interior of the earth which could not be acquired otherwise. The local differences in gravitational force from place to place are of considerable interest to many industries. By means of these differences and other geophysical data it is possible to locate mineral resources and to determine some types of geological substructure associ-

ated with deposits of oil. In certain regions the gravitational force is markedly different from the average. Some of these regions are subject to frequent earthquakes. The system of geodetic mapping of this country enables one to ascertain the magnitude of earthquake-movements; it also reveals gradual deformations taking place in the earth's crust which in a number of cases appear to be the precursors of earthquakes.

Seismology

While man may modify climate by encouraging certain forms of vegetation, may stem floods by the construction of dams and may transform deserts into fertile valleys by irrigation, it does not seem possible that he may ever prevent those tremors of the earth which wreck even the stoutest of his structures. However, progress in seismology has done much to mitigate the disasters which attend earthquakes. Investigation of the nature of the movements during earthquakes yields information as to the type of building which will suffer least during such a disaster. Regions which are most subject to earthquakes have been mapped out and the active fault-lines in inhabited

Photo by courtesy United States Coast and Geodetic Survey.

GEODETIC OBSERVER ON PEAK IN THE ROCKIES

PRECARIOUS POSITIONS MUST BE OCCUPIED TO PRESERVE INTERVISIBILITY BETWEEN ADJACENT GEODETIC STATIONS. BENCH-MARKS HAVE BEEN ESTABLISHED ON MANY OF THE HIGHEST MOUNTAINS IN THE UNITED STATES FOR FUTURE REFERENCE IN MAPPING.

regions are well known. The accumulation of authentic data is now permitting insurance companies to establish rates for insurance against earthquakes on a more rational basis than hithertofore. Attempts are now being made to discover conditions which may indicate a future earthquake before it occurs—measurements of gradual tilting of rocks and of slow displacements of the land.

Knowledge of how seismic waves are transmitted through the earth's crust has found useful application in the investigation of geologic structure. By setting off explosives buried in the earth and recording the echoes of the explosive wave as it is returned from the various underlying strata, it is possible to ascertain their nature and depth. This is one of the most effective methods for discovering hidden mineral resources. It has also found application in mapping sub-crustal rock-structure for highway construction and other engineering projects.

Photo by courtesy Portland Cement Association.

SURVIVAL OF THE FITTEST IN THE LONG BEACH EARTHQUAKE

MODERN STRUCTURES OF EARTHQUAKE-RESISTANT DESIGN WERE UNDAMAGED IN THE DISASTROUS LONG BEACH EARTHQUAKE WHILE BUILDINGS OF ORDINARY CONSTRUCTION WERE LEVELED. ALTHOUGH THE EARTHQUAKE SHOCK WAS NOT USUALLY SEVERE THE ALLUVIUM UPON WHICH LONG BEACH WAS BUILT SHOOK LIKE A BOWL OF JELLY. BUILDINGS IN SUCH REGIONS REQUIRE SPECIAL DESIGN.

Volcanology

Man may never hope to extinguish the apparent fires of Vesuvius, but one may imagine how different would have been the history of Pompeii and Herculaneum had modern volcanological knowledge been available to the inhabitants of those ill-fated cities. To-day observatories are maintained on several volcanic cones which reveal the mumbled threats of the subterranean forces against the people who dwell in the region.

Accurate prediction of volcanic eruptions is not feasible at the present time. But since many volcanic regions have proven favorable for human habitation, the hope of accurate prediction leads volcanologists onward. The behavior of certain volcanoes has been so intensively studied that nearby dwellers sometimes may be warned of impending disasters. To foretell the exact time of an eruption may never be possible, but certain premonitory signs such as changing character of neighboring hot springs and fumaroles, and especially increasing intensity of subterranean noises, systematically watched, frequently give warning of impending disaster.

The claim is now made that an active eruption in any well-known volcano can

Photo by courtesy Department of Terrestrial Magnetism, Carnegie Institution of Washington.

THE MAGNETIC SURVEY VESSEL *CARNEGIE*

CONSTRUCTED ENTIRELY OF NON-MAGNETIC MATERIALS SO THAT HER SENSITIVE INSTRUMENTS WOULD GIVE ACCURATE READINGS, THIS VESSEL CRUISED 250,000 MILES TO DETERMINE COMPASS-DIRECTION AND MAGNETIC FORCE IN VARIOUS PARTS OF THE WORLD. OBSERVATIONS OF ATMOSPHERIC ELECTRICITY, COSMIC RAYS, WEATHER AND OCEANIC CONDITIONS ALL OVER THE GLOBE WERE ALSO INCLUDED IN THE SCIENTIFIC PROGRAM INTERRUPTED BY HER DESTRUCTION BY FIRE IN 1929. THE BRITISH ADMIRALTY IS BUILDING A LIKE VESSEL TO CONTINUE THE *Carnegie's* WORK.

Photo by courtesy of the Geophysical Laboratory, Carnegie Institution of Washington.

MOUNT LASSEN IN CALIFORNIA AFTER ERUPTION OF 1914

THIS IS THE ONLY VOLCANO WITHIN THE BOUNDARIES OF THE UNITED STATES WHICH HAS BEEN ACTIVE WITHIN THE MEMORY OF LIVING MEN. MANY SQUARE MILES OF FOREST DEVASTATED BY EXPLOSIVE ERUPTIONS OF THIS VOLCANO TESTIFY TO THE NEED FOR VOLCANOLOGICAL STUDIES IN THIS COUNTRY.

be diagnosed by an expert in a comparatively short time, the results enabling him to determine whether its intensity is declining or whether further dangerous outbreaks are at hand. A half-dozen such predictions of volcanic outbursts in Japan, Italy, Martinique and the Azores have proved correct. If these criteria are shown to be of general application, they are obviously of the greatest importance to mankind.

But these Cyclopean monsters, so terrible in their angry moods, are not wholly lacking in virtue. Volcanoes are sources for many valuable minerals which they yield up quite readily. In a few cases their power may be harnessed to serve man's needs. In Italy superheated steam of volcanic origin is used to drive turbines and generate electricity. At the same time volatile volcanic products accompanying the steam, especially boric acid, ammonia and carbon dioxide, are recovered and they and their derivatives are sold in the market. Hot springs, another phase of volcanic activity, produce water of recognized therapeutic value, while the warm waters from the springs in Iceland and other places are coming into use for heating buildings and other purposes.

Terrestrial Magnetism

The progress of navigation on the high seas resulting from the development of the mariner's compass forms an interesting chapter in the history of civilization. Although to-day large ships carry gyrocompasses and flights of airplane are frequently directed by radio beacons, the old-fashioned mariner's compass is still used to aid navigation, and for less pretentious modes of travel in smaller vessels absolute dependence is placed on it. Definition of boundary-lines in terms of the compass requires knowledge of the exact magnetic bearing over the land. Since the compass does not point truly north, except in a few places, and since the deviation of the compass from true north changes from year to year, it is necessary to know the error of the compass at all places on the earth and the rate at which the error changes from year to year. Unfortunately the investigations of these phenomena have been limited to too short a time for an accurate prediction of what the compass-direction will be at any one place at any given time in the future, if it is predictable. Continued determination of direction of the compass at many widely distributed places is therefore necessary.

Apart from its application in determining direction, study of terrestrial magnetism is important because of sudden disturbances of the magnetic field called "storms." These storms, accompanied by flashes of auroral light in the polar sky, play havoc with radio communication. Daily observations of terrestrial magnetism which have been conducted for nearly a century have revealed the idiosyncrasies of these magnetic storms so that a basis for their prediction has been developed. The likelihood of a magnetic storm occurring is taken into account in scheduling international broadcasts.

Magnetic storms are due to conditions on the sun as attested by their correlation with sunspots. But since magnetic storms sometimes occur when no spots are visible upon the sun, it must be recognized that the magnetic storms indicate changing solar conditions which are not otherwise observable. In astronomical language, our sun is a "variable star." When one considers what has happened to some stars in the sky—tremendous explosions or sudden shrinkings to practical extinction—he must be aware of the importance of keeping track of the behavior of that one heavenly body upon which terrestrial life so intimately depends.

The small differences of magnetic force from place to place which complicate the compass-charts have their useful aspects. They enable the geophysical prospector to define the underlying strata by their effect on the magnetic force at

ONE OF THE OLD VOLCANO WITHIN THE BOUNDARIES OF THE UNITED STATES WHICH HAS BEEN ACTIVE WITHIN THE MEMORY OF LIVING MEN. MANY SQUARE MILES OF FOREST DEVASTATED BY EXPLOSIVE ERUPTIONS OF THIS VOLCANO TESTIFY TO THE NEED FOR VOLCANOLOGICAL STUDIES IN THIS COUNTRY.

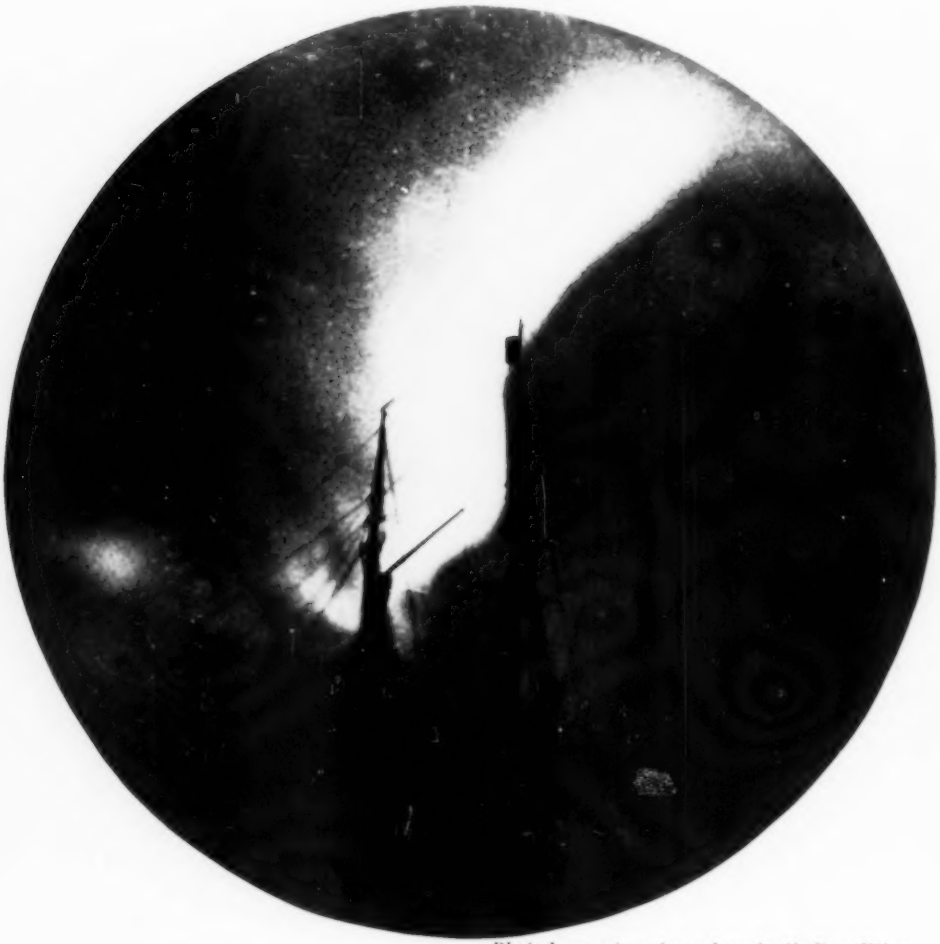

Photo by courtesy Amundsen Arctic Expedition.

AURORAL DISPLAY OVER THE ICE-BOUND ARCTIC SEAS

STUDY OF THE AURORA IMPROVES OUR KNOWLEDGE OF THE UPPER ATMOSPHERE WHICH HAS IMPORTANT BEARING ON RADIO COMMUNICATION AND OTHER TERRESTRIAL PHENOMENA. GREAT AURORAL DISPLAYS ACCOMPANY MAGNETIC STORMS WHICH INTERFERE WITH COMMUNICATION BY RADIO, TELEPHONE AND TELEGRAPH.

the earth's surface. Already this means has been employed for locating places where oil and other mineral resources may be found—a far cheaper method than digging into the earth or running bore-holes through many feet of rock to discover the treasures which nature has so carefully hidden from us.

Terrestrial Electricity

Magnetic research has led to the investigation of natural electric currents which flow in the earth's crust. Their effect upon pipe-lines and other extensive metallic structures imbedded in the earth has received much consideration. How to avert their effects on the corrosion of the metals is a study in itself. Closely related to changes in the earth's magnetism, these earth-currents have strong effects on telegraph and telephone lines during magnetic storms, frequently putting them out of commission.

Since the substance of the earth con-

ducts an electric current, though not uniformly, geophysicists have become interested in the electrical resistance of various types of soil and rocks. To measure the resistance of the soil it is not necessary to remove it from its place, however. Methods have been devised for measuring the resistance of layers many hundreds of feet below the surface. Since rocks of various types, dry soil and water-levels all have different resistances, it is possible to apprehend the composition of various layers beneath the surface by measuring their resistance. Thus the geophysical prospector is able to detect the presence of mineral deposits, locate water-levels and define bedrock for the engineer who would tap these natural reservoirs or build his structures upon firm foundations.

Atmospheric Electricity

Man has been aware for all time of certain atmospheric-electric phenomena. He has seen the lightning strike with devastating effect. Fortunately, lightning hazards are avoidable by the application of modern science. The crude lightning-rod invented by Franklin furnished adequate protection in its day, but the present development of lengthy electric power lines requires a protection based upon a more comprehensive knowledge of the electric phenomena of the atmosphere.

Even during fair weather, atmospheric-electric phenomena manifest themselves. The study of the electrified particles in the atmosphere has attracted considerable attention, particularly from the viewpoint of their effect on human health. Closely connected with this study is the consideration of atmospheric pollution poured out by our large factories with their threat against human well-being.

The applications of geophysics promoting the general welfare of mankind are legion. That so many uses for the facts of the science have already been found suggests that there are many more which the further specialization of modern life will discover. Matters which a decade ago were considered purely theoretical have found many practical applications in the present. Furtherance of geophysical science, both theoretical and applied, will earn as creditable a reputation in the future as it has in the past. A thorough understanding and a sane exploitation of the earth is essential lest man in his own folly make this planet no longer habitable for the human race.

THE MEANING OF MEDICAL RESEARCH[1]

By Dr. ALFRED E. COHN

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You may expect from me a description of discoveries, dramatic and exciting perhaps; of new diseases or of the mechanisms underlying diseases already identified; of new drugs which cure, like sulphanilamide; or of new operations which relieve or prevent devastating conditions. I could enliven this report by such narratives, as for example the great new insights which have resulted from studying the pituitary gland seriously. The investigation of this organ by Cushing who gave the forward movement a great impetus and by many other very capable and ingenious investigators, has resulted in the description of new ailments, has given point to the attempt to understand the interrelations of fluids and tissues and organs, in ways and to extents not dreamed of ten years ago; has made available agents of real power in adjusting defaulting or erring mechanisms. Or in a sense less pathological and more physiological, describe how great has been the increase in knowledge of the behavior of such important tissues as muscle and nerve. To speak of any one adequately would cost all my time. There are other ample provisions, however, for spreading that sort of information. My task is both simpler and more complicated. I am to speak of what research in medicine "means," what its nature is and what its purposes. And I take that to include an inquiry into its position in the complicated matrix of our social structure.

The ultimate meaning or purpose of medical research is to rid men of diseases, to protect them from maladies with which they are threatened, to relieve them of discomforts once they are established. There are many diseases, differing in the degree of dangerousness, differing in nature, differing in geographic distribution. There are pathological states to the existence of which we are sensitive—others which, for various reasons, we ignore. Then there is the character of education, having its sources and momentum in the contemporary scene, which makes men fit to undertake chiefly what is comprehensible in that scene. Researches are delayed because points of importance are missed, scholars being unprepared to comprehend them and to seize their opportunities. Researches are sometimes hurried, wasteful and erroneous, because the idea is entertained that current equipment is adequate to deal with particular problems. The question of public versus private scholarship is important—less important now when the whole situation of research is better understood, and when private scholarship is recognized as being less private than formerly. Private refers both to financial resources sufficient to free scholars from the restrictions imposed upon the use of public funds; and to intellectual latitude which makes room for personal vagary, for unorthodoxy, which may not be tolerated even in an academic environment. But greater in importance than either, because essential, is the pervasiveness of current belief and opinion, current social need, the implications in the current social scene, which tend to influence or perhaps better which do not permit us to escape current intellectual compulsions. These are aspects of the

[1] The third lecture to the laity (1937–8 Series), delivered on November 24, 1937, at the New York Academy of Medicine.

intellectual life of which Hessen and his followers have made us aware.[2]

The meaning of medical research must regard these various social and personal aspects. It must regard also the nexus which exists between medical and other sciences. It must make an effort to understand likenesses and differences which characterize medicine in relation to those other sciences. It must analyze the situations, diseases and social pressures, to which energy is devoted and must describe the means, in men and facilities, which are available for carrying them out.

I propose to speak first of *what* we study; second of *how* we study it; third, of *who* does the studying; and finally in the course of this discussion *for what reason* does the study take place.

When these far reaching issues and conceptions are being canvassed there must first be described certain situations which the world of diseases presents to investigators. It has already been suggested that these vary with time and place. We do not study those diseases which do not exist—or which exist elsewhere, or which exist no longer. The impulse to study a given disease or a given hygienic circumstance results from the danger or the damage which its presence causes. Epidemics of diseases like the black death or of poliomyelitis, or of influenza, or of cholera can scarcely or safely be ignored. But not many of the resources of this community are devoted to yellow fever or kala-azar, or African sleeping sickness. If these diseases were, by their maritime introduction, to threaten the local population, a study of them would be inescapable. They are studied though for several reasons; a general philanthropic motive; because, as in the opinion of Dr. Albert Schweitzer, restitution should be made by a people for the injury done another; because, to study them is imperative to preserve health along international trade routes. Pressure of some sort is usually experienced or is exercised when a study is undertaken.

Of the diseases which we do study, there are several kinds. It is of very great importance to understand that diseases can not, all of them, be regarded as forming a system. They can be grouped, as indeed they are, to form several systems. The various systems have, superficially at least, little in common except that they transform the individuals whom they afflict.[3] Each group, on the other hand, exhibits traits which leave none or little doubt as to the relatedness of the members.

The center of gravity of interest in diseases has long, roughly for two generations, lain in *infectious* and *epidemic diseases*. To understand them and to cure them, the sciences which needed to be and which were and are actively cultivated are bacteriology and parasitology —these two in some respects similar. More recently diseases resulting from viruses, agents of far smaller dimensions than bacteria, have been added to the list. These diseases all depend on the invasion of animal and plant organisms

[2] It would be interesting and important to study the nature of social pressure, using this term in its widest sense, in the province of diseases. It is a point of view not strange to historians and students of social phenomena, but one not yet much employed in medical thinking. The illustrations in this essay have been drawn chiefly from communicable diseases and from a few other maladies differently grouped. But the relations exhibited by the development of knowledge of nutrition, or of understanding chemical processes on which nutrition depends, of agricultural growth, of social change in which the demands on the food supply of the less favored receive more sympathetic recognition—all these are matters which lie for analysis at the door of the critic. Here, as elsewhere, these and other factors require study in a complete account of the processes at work in a community.

[3] A disease is not an "entity"—it is a transformed organism. The organism is conditioned for exhibiting disease by processes which dispose it to this exhibition. The preparation may be constitutional or psychological or local—but the transformed organism is transformed, not solely by what is called an invader.

by these agents. Parallel with bacteriology and parasitology, sciences roughly grouped as immunological have been developed, in which there have been studied the reactions, that is to say, the behavior of the hosts, plants and animals, which the infectious agents invade. Studies of immunity have gone farther though than the study of individual hosts when under attack. A science of epidemiology has grown alongside the other sciences in order to study the conditions in which societies of men, animals, and plants, chance to become prepared for invasion by infecting agents. These include external factors—climate, race, season, sunlight; and internal factors, the blood, the plasma, certain organs and tissues, heredity. To cope with these invasions, efforts in various directions have sedulously been made—with sera, which utilize the forces animal bodies themselves prepare for their protection; with chemicals, like salvarsan, like optochin, like arsphenamine, sulphanilamide—all synthetized with the utmost chemical skill; with natural pharmacal agents, chaulmoogra oil, quinine, salicylates. These are, in a sense, beginnings, the success of which points to the fact that the way of thinking about such problems as they represent, is sound and therefore encouraging. Much more may be expected from such efforts. Indeed, not more than auspicious beginnings have been made.

A point of importance, later to be referred to, is that the successes, still in many instances not more than partial, have been attained by delving below the surface of naturally existing phenomena, of appearances, to learn on what these diseases depend. The rewarding results have been that bacteria have been found, and protozoa and viruses. With this kind of knowledge as a background, substances of many sorts were and are being sought, to oppose the action of the invaders. Here are the rudiments, I may mention in passing, of analytical procedures. They represent something new in the study of diseases. Compared to the amount of energy which has been expended, the success so far achieved has, quite obviously, been extraordinary.

Infectious or contagious or epidemic diseases have often been characterized as acute. Acute means two things—that individuals are seized suddenly with disability, a matter of hours or minutes; and also that their duration is usually brief—though there are numerous exceptions, as tuberculosis, syphilis and leprosy.

But there are long drawn out ailments, often called *chronic*, which fall into two great groups. Certain ones occur at all ages, like pernicious anaemia or diabetes mellitus. But there are others which befall older persons exclusively. I designate these, "ailments" and not diseases, nor yet degenerative—two words often applied to them which I prefer not to use, for reasons which I hope later to develop.

To distinguish diseases merely according to their duration is a crude conception. But to do so has a use, for the time being. Chronic has usually been intended to signify long drawn out. Roughly, chronic and long drawn out mean the same thing. From the point of view of patients and their families, duration is important; and from that of administrators concerned with the public health the distinction is essential. Actually what is involved is the rate at which the processes in different maladies advances. Chronic diseases or long drawn out maladies include a wide range of complaints. Their duration is to be estimated, naturally from their beginning to their termination, uninfluenced, when such examples are available, by treatment. The group is diverse—there are, for example, the diseases of the blood forming organs—pernicious anaemia, leukaemia, thrombocytopenia; there is cancer, there is tuberculosis; there are the deformities of the joints; there are cardiac and arterial de-

rangements; there are the defects which result from insufficience or mal-function of the glands of internal secretion—the hormones in short; there are diseases of the nervous system. It has been customary to divide diseases into three, or perhaps better two, main groups as I am doing; bacteriological and physiological both, but the latter especially employing physical and chemical techniques. Chronic diseases fall into each of them. These categories require in certain instances to be stretched fairly wide, in order to include all the varieties. But they will serve for this discussion, especially if in studying bacterial diseases, the behavior of the host, immunology, is included; and if in the physiological ones, anatomical defects and malformations.

It is sufficient, I think, to suggest that medicine deals with many kinds of conditions and that they fall roughly into the categories that have been indicated. Of chief moment is that the classification, though rough, suffices to indicate that well characterized groups can be recognized and that, through this possibility, study is facilitated, perhaps made possible.

Now it is generally understood and indeed it must be obvious that when a malady or any other natural phenomenon begins to be *analyzed* (analysis being the method essential to experimental research) very soon a level of organization is reached, less complex than the native state of a whole plant or animal, the study of which requires recourse to a chemical laboratory. This is due to the fact that biological mechanisms, when the attempt is made to view them more simply, break down promptly to chemical processes. In physiological diseases, especially those of the heart and arteries, in parallel fashion, a stage is reached when mechanical and physical appliances are needed to help in understanding what is going on. To turn to chemistry, to mechanics, to physics, is to turn not so much to fundamental things as to machinery which underlies and which determines more complex, directly observable behaviors. These disciplines —physics, chemistry, immunology—constitute the techniques which are used to analyze, to reduce to simpler, more easily understandable mechanisms, the surface appearance of maladies. The fact that this is the situation in research in diseases constitutes a dilemma. To this problem it will be necessary to return.

I have referred to *two kinds of chronic diseases*—one which can occur at any age and one which is characteristic of the aged. Those diseases characteristic of the *aged* require especial description because, though they are not new, they are beginning to take on new significance. We grow older, all of us. As is well known, in the course of doing so we fall subject predominantly to several distinct kinds of disabilities. I pass over cancer; its nature and its ravages are in every one's mind. But what happens to the heart, the arteries, and the kidneys, has been less clearly appreciated. I do not wish to discuss all the possibilities, all the theories. One theory ought I think to be more fully described. In the sense that everybody ages, aging has come to be looked upon as a natural phenomenon —natural as differing from accident or from chance. Since every one ages, aging is anticipated and the separate phenomena of aging are looked upon as predictable. This has been a subject of very active research in recent years. And the objectives in such researches have been twofold; first, to ascertain as precisely as possible a picture of what actually takes place and second, to discover what mechanisms are at work to bring about such results. I single out the arteries for more detailed description. That the arteries change is now universally known, especially the great artery of the body, the aorta. What is less well known is that the smaller ones do also. Arteries which have come in

for marked attention in recent years are those of the heart—the coronary arteries. The walls of arteries may be thought of as having layers or coats. In the coronary arteries, for example, the first detectable changes take place in the innermost layer; its elastic membrane splits in two and does so rather early in life—in the twenties. From then on, more and more changes take place. At 50 or 60 these changes are advanced and have been termed arterio-sclerosis. To one familiar with the succession of these appearances, it is possible to tell their age within a few years. Being able to do this is good evidence that there is nothing haphazard about the process. How are these systematic changes brought about? And how, assuming that they develop systematically, can they be prevented or delayed? To answer these questions, guesses have been ventured since very early times and to explain them, serious, far-reaching researches have been undertaken. But so far there are no answers satisfactory to many scientists. Meanwhile the quest goes on, with intensifying earnestness. The problem, as I shall show presently, is urgent. What is true of the arteries of the heart is true of those of the brain. About other organs less is known. Progressive alterations, appropriate to each organ and tissue, go on throughout the body—beside the heart muscle, in the kidneys, in the liver—everywhere in short.

But changes in structure do not alone exhibit progressive alteration. Comparable ones can be observed also in the functioning of the body. The slow and gradual rise with age which the blood pressures exhibit are well known. Another striking one has recently been found in the nutrition of the body. Here, it appears that ptyalin, the starch-splitting ferment of the saliva, decreases between 25 and 81 (these are averages) to one thirty-fourth, necessitating, it seems probable, a very striking readjustment in digestion and food requirements in the aged. More intimate still are changes in behavior of the muscle fibers of the heart. It has been shown in dogs, for example, that as the animals grow older, the ability of this tissue to utilize oxygen diminishes significantly. Finally, as in changes in structure and in function, so also, it appears can changes in psychological performance be detected. Interest in this phase of growth has begun more recently, so that it would be rash to accept the results of preliminary studies. There can be little doubt though that this is a fruitful field for further investigation.[4]

Many regard it as an idle question, but it is one which should be put nevertheless—are processes so universal as are those identified with aging to be classed with diseases? Diseases are not constant; they wax and wane; new ones occur; old ones vanish; they are unlooked for; they are recovered from. Of the changes which accompany aging, none of these characteristics can be predicated. It seems better to weigh the question of the nature of this process of aging a while longer, before coming to a decision on its nature. Two ways of thinking are possible—that aging is an accident which can be prevented; or that it is not an accident and that, as the body increases in bulk and by so doing is said to grow, parallel changes are taking place within the body, in its most intimate recesses, which accompany that growth, and which themselves may be regarded as taking part in and perhaps constituting the phenomena of growth. In this sense the body grows continuously, changes, called differentiation, taking place in all its parts, the form of change passing from

[4] This reference to psychological matters is brief because I am depending on other phases of this problem for illustration. But the place in human nature and in diseases which psychological deviations occupy can scarcely be overemphasized. I am at one with those who wish to understand organisms as wholes and to return from the wilderness into which the requirements of thought in the 17th century naturally led us.

stage to stage without break until the final dissolution. This view urges that there is only one forward moving change —not, first growth and then degeneration, but continuous progressive differentiation. And growth so understood is not an accident, it is not degeneration—and it is not disease.

These old ailments present a new challenge. To care for them is becoming a great burden, financially. Can anything be done to relieve the strain? Medical research, not yet very consciously, is struggling with the question. It has no settled answer. When such questions were first raised fifteen years ago, we were not yet ready to weigh them. Now the response may become, is indeed becoming, more intelligent. The old hospitals built for infectious diseases will no longer serve. In part they are improperly constructed for these purposes. And from the point of view of research, the new situation calls for new orientation. It is still inescapable that research in infectious diseases continue here and elsewhere. Here because there is still tuberculosis, syphilis, poliomyelitis and other infections of the nervous system, rheumatic fever and influenza; elsewhere, in the tropics, because of diseases indigenous there, but perhaps transplantable here. But since the dawn of that era in which we have spent our lives, the emphasis has been almost exclusively on diseases of this kind. It would be incorrect to say that diseases longer drawn out at older ages had been neglected—cancer for example or cardiac diseases. But it is certain that in comparison with infectious diseases, they have been much less cared for and studied. The great desideratum now, is to turn increasing attention to these conditions. If they were better understood, it might become possible to manage them better. If they were better treated, expensive care in homes, and in institutions might be less necessary; if they were less expensively treated, the burden of taxation might diminish. The net result would accrue vastly to the sufferers themselves—in increased health, in greater freedom spent outside of institutions, in greater economic self-sufficiency. Psychologically, the lives of older men and women might be re-made if we learned how to make them self-sufficient to a degree impossible now, through a new orientation to employment, utilizing opportunities for activity appropriate to the aged. Embedded in the matrix of our society, no better fate is provided for them or envisaged than progressive deterioration.

I have been speaking of *what* we study. I come now to speak of *how* we do so. After long reflection and practical experience there has come to be general comprehension of the purposes and methods of the sciences in general. By the same token, a similar statement can be made of medical science. But in some subtle way, there is tacit agreement that the two are in essence, somehow different. Whether they are, depends I think upon the aspect from which this judgment is made. They do not differ, there would be general agreement, in attitude to natural phenomena; nor do they differ in the seriousness with which the problems of diseases are studied; nor do they differ in the methods which both, or all, use. To recognize and to point out differences is not invidious; no more is intended than to understand a complicated situation.

Two suggest themselves—first, one having to do with the nature of the subject matter—and second, one having to do with the circumstances conditioning the activities of students of diseases. The former difference, in subject matter, has, I venture to believe, a certain validity[5];

[5] It is perhaps a superficial experience but one to which large numbers of persons are sensitive, that in a very general sense, diseases are ugly, repellant, offensive. These are not qualities which characterize phenomena studied in other sciences. The reverse may and often is true. It is of course a fact that to many men, perhaps especially to physicians, this aspect of disease is without meaning. It may be that to them the

the second, I think, not. To begin with, though it is not my intention to become involved merely in words, it is well to make clear the meaning I ascribe to certain terms.

Science, very briefly, is a way of looking at nature, in so far as that is possible, exactly. Two aspects are involved—the natural phenomena themselves and a way of looking.

Research is procedure. Research represents the effort men make to increase their comprehension. To discover what is true about anything is an arduous undertaking because, at the outset, so many things seem possibly correct. That is why research is an adventure.

The object of the whole enterprise is to *describe* nature.[6] At first it seems wise, at all events it seems to have been universally customary, to describe natural phenomena so as to group them. That makes description easier because there result fewer descriptions. Classification is what this phase of the undertaking is called. Sometimes, especially in our day, there lurks unfortunately, something invidious in the remark that an investigator is merely "describing." Descriptions must naturally be exact. Exactness can in fact be exhibited, purely and deliberately, without quantitative expression, in descriptions of things as they occur in nature, rough and in the whole. Men who have carried on this phase of natural enquiry have been known as naturalists or, at a stage more organized, more complicated, systematists. Hippocrates, Pliny, Linnaeus, Sydenham, Darwin, Lyell, Audubon, Wheeler, form such a group. Their very names are proof that nothing derogatory attaches to their interests or their methods. Without labors like theirs, there can be no natural science. Without them we should be talking of phoenixes, unicorns and other mythological animals. It is an evidence of the literalness of the culture of the Greeks that, unlike Egyptians or Orientals, they entered little into nature faking. The objects of concern to scientists have been natural objects. Later—and later may be taken to have a chronological meaning, though it may have also a logical one—when the *experimental era* began in its modern form, reliance came to be placed, not by any means exclusively but accompanied by a certain glamor which obscured the relations among methods, on the experimental method. A powerful agent for extending knowledge became available. The experimental method involves the conception that comprehension of a thing, of a phenomenon, can be furthered powerfully by dissecting it, by pulling it apart, by measuring and by weighing and by counting.[7] I need not dwell on, what is universally known, the extraordinary and unbelievable success of the method. By it Galilei, Harvey, Newton, Young, Lavoisier, their modern equally great successors and an enormous host of followers have enriched modern thought, modern knowledge and modern life.

When the experimental era began in its modern form, the temptation was great to believe that, once the parts were known, the whole would be comprehended. It was another way of thinking

very fact of ugliness has the value of attractiveness. Nor need this be regarded as odd. The last word on the subject of ugliness has not been uttered—in sight, sound, or form.

[6] There are those to whom action appears a more impressive and compelling motive than description. The object of the enterprise would then be to accomplish an end. The difference may be essential but it may also be a difference in emphasis. If astronomy began in the interests of action, it has remained a means to satisfy mere curiosity; or—is it perhaps to return to its original function?

[7] It needs scarcely to be pointed out that what is called synthesis, as in the preparation of chemical substances, dyes for example, or aromatic compounds or in metallurgy when new alloys are made or in technical procedures or advances in general, is an extension merely of the analytical process.

that the whole is equal to the sum of the parts. But doubt began to assail thinkers that matters were not so simple. It was the same situation that confronted the King's horses and the King's men when they tried, after his great fall, to put Humpty Dumpty together again. The attempt did not work. Because it did not and because in a very widespread manner there is current conviction that it can not, the idea has been put forward by S. Alexander, Lloyd Morgan, A. N. Whitehead and General Smuts that, in putting things together again after they have been taken apart, something new becomes ingredient, something not in the constituent elements. It is, to use a crude example, as if 2+2 did not quite equal 4—that to attain 4, something not in the synthesizer's hands or mind, entered into the new composition. The doctrine that something new occurs has come to be known as emergent evolution. In speaking of analysis and research, it is unnecessary to lay undue emphasis on the imperfections of the analytical process, but it is desirable to be alive to their existence so as to avoid the disappointments which otherwise are almost inescapable. There have in point of fact been a goodly number. Leaving aside the emergence of new qualities, a phase after all of synthesis, the delays which have taken place in the cures of infectious diseases, like tuberculosis, like typhoid fever, like poliomyelitis, after the discovery and identification of the agents that help to occasion them, are known to everybody.

The whole adventure, classification and analysis, is science. I said it had two aspects, the natural phenomena themselves and a way of looking. Of the way of looking, there has just been discussion. Of the natural phenomena, there is something to say concerning a significant difference between medical and other natural sciences, the difference to which I wished to direct attention and which I wish briefly to weigh. It is the *enduring interest* that attaches to other natural sciences in contrast with the medical ones. Consider such interests as the origin of species, the origin of astronomical systems, matter, heat, electricity, the formation of the earth, light, heredity. These are concerns as little influenced as may be by time and place. There was never a time when they did not engage serious intellectual attention; they do so now; there is good reason to believe they will continue to do so. These phenomena awoke and continue to awake enduring interests because they are enduring objects.

Turn next to the situation in the study of diseases. I have been dwelling on enduringness in interest in the objects of natural science because the objects studied in these sciences are themselves enduring. Now diseases, whether of plants or of animals, no matter what their nature, are statistically something extra.[8] They are occurrences which, in subtle or coarse ways, change the usual behavior of living things. The organisms are said to suffer—hence the use of the word, in the British sense, pathology. Beside being something extra, their becoming established in a society is not permanent. They change with time, they change with locality. The sweating sickness is gone. How long poliomyelitis may have existed is not known. Diseases devastating in the tropics do not exist in the temperate zones. In other cases, like rheumatic fever, the reverse may be true. Diseases may continue to turn out to be transient sojourners. By paying a necessary price, there are diseases of which we can rid ourselves—syphilis for example, perhaps scarlet

[8] Extra—not anticipated in a state of "health." I do not mean that process "a" is joined to organism "b" and that a+b constitute a disease. In this sense a would be what has been called an entity—an "ens." That is far from my meaning. "Extra" describes the whole organism, exhibiting phenomena, not counted as occurring in health. Health itself is a statistical conception.

fever, no doubt a number of others. Diseases, furthermore, have no independent existence; they are recognized when they have transformed the nature of their hosts, plant or animal, temporarily or permanently.

If, as I have been surmising, enduringness is a characteristic of things which have become constituted objects of study in natural sciences, it seems apparent that diseases do not partake of that quality. That is clearly the case in infectious diseases. Nor in all probability do chemical diseases, of which the deficiency states are examples, pellagra, pernicious anaemia, rickets and scurvy. Another group of diseases of great importance may be designated physiological. Physiology may be termed the study of the living behavior of an organism, as different from its mere structure. In the study of diseases, the physiology of an animal has importance because it occupies a place like the study of metallurgy in the mechanism of a steam engine. But a disease is not merely quantitatively changed physiology. A disease is something over and above and therefore different from this. The place of physiology in this scheme must not be confused. Physiology undertakes the analysis of something, animal or plant, reasonably long enduring in a species or a genus—the circulation, reproduction, digestion. These are mechanisms which are neither temporary nor local. There are of course physiological derangements which are usually called diseases, eclampsia being an example or perhaps a certain variety of arterial hypertension, or fibrillation of the auricles of the heart, or psychogenic hyperthyroidism. And a special case is that of senescence—the aging through which we all pass. My case as to enduringness is naturally not as clear-cut in respect to physiological occurrences as the distinction I have drawn suggests. Evolution and the disappearance of species and genera see to that. But there is enough of background for this distinction to occasion the social consequences in which can be perceived, implications of great importance to the position the study of medicine occupies.[9]

I wish now to examine the use of another word. The word "*empiricism*" provides an opportunity for examining certain ideas and procedures commonly employed in natural science. When a certain amount of animadversion is intended in the use of the word, the adjective "crude" is prefixed. This phrase "crude empiricism" has been used especially with reference to the study of diseases, the assumption being that the study of diseases is something apart, in fact, from other studies of natural phenomena—something perhaps a little backward. On more careful reflection it becomes clear that "crude empiricism" is a phrase universally applicable to a level of discovery at which, what is called "thinking" has not been much employed or, can not be, either in the existing state of knowledge or by the individuals who indulge in that occupation. Now, when what is called "crude empiricism" is exhibited, the subject matter under investigation is relatively in a raw native state and the means which are used to analyze that subject matter are not, in comparison with what is possible elsewhere, or in some other discipline, of a sort to be called refined. An example in medicine

[9] There is a point of view from which contributions to general knowledge result from the study of ephemeral phenomena or from acquaintance with transient experience. Contributions so derived can, no doubt, exert significant influence in developing insights, conceptions and procedures which come much later to fruition. Broad intellectual streams can originate in obscure rills. But there remains nevertheless a value which enduringness, as a method of characterization, can be made to possess. Even so, as a characteristic, it is unnecessary to assume that it has more than relative value. Were diseases dependent on a relation to bacteria wholly to disappear, bacteriology, for example, having received its great stimulus from this association, may be expected to remain an important interest nevertheless, because of the growing place it is coming to occupy in agriculture and elsewhere.

is the use of quinine in malaria, before an insight into the nature of malaria or the composition of quinine was obtained. Syphilis and mercury is another example, or dropsy and digitalis. In physical science, telephony and the nature of electricity, though a very rough analogue, may serve as example. The form in which I have stated this situation suggests its meaning. When something is done or some interference with a system is undertaken, as in the examples just given, it is in the natural organized state of the material, the crude, native state, in which the operation is performed. There exists no guide, furthermore, to suggest what form the operation should take. If malaria is not known to be protozoal in origin, or if it is unknown that the infecting agent is susceptible to quinine, but a therapeutic attempt is made, none-the-less—that attempt is empirical and may be termed crude. That it should be so is in the nature of things. If the object is to understand—anything whatever, a beginning must be (or is) made. Once a beginning is made, successive efforts at understanding, if on the road to success, become less and less "crude." In the case of matter, electricity, energy, methods of analysis have now become so refined that it is evident how long a distance has been travelled from rubbing cat's fur on amber (electron). The more we analyze, the further investigation becomes removed from crudity. Because analysis has taken place in successive simple stages; because, covering the heart of a phenomenon, there are layers of impenetrability, like the layers of petals covering the heart of an artichoke, Sherrington was moved to say, because that is the way an experimenter must look at the world, behind each mechanism is hidden another mechanism. Obviously the metaphor of the artichoke is imperfect—there is a last layer of leaves, small and apparently confused in arrangement, and then the heart. But in the phenomena to which scientists devote themselves, who knows when the last petal has been plucked and the heart of a natural process uncovered? There is a chance here (and the man who knows how to take it is the artist in science) that for *an* object, it is unnecessary—no, destructive in fact, to go further than a certain point—the point being the emergent level for which search was being made. Protection against pneumonia will not, by way of illustration, be solved at the atomic level. If the appropriate level is passed, the nature of the thing sought may elude one's grasp. Hawthorne's story of the birthmark and beauty tells the story of the devastation wrought by a perfectionist.

Whether knowledge is empirical depends often on the standpoint of the critic. A molecule, a protein molecule, may seem very refined in comparison with a man, but to an electron it looks enormously complex. The whole business is relative.

The point about empiricism and crudeness requires no further laboring. It must be apparent that at the beginning nothing else than crudeness is possible. Later on more insight may have been gained, but the term will still be applicable. Were the case of causation simple, as it is not, it would be possible to prescribe how a situation must be analyzed and possible to prophesy the results. There is little confidence nowadays that that can be the situation anywhere. Further understanding depends therefore on trial and error in the choice of analytical techniques. Since that is inescapable all scientific analysis is crude and all knowledge empirical. The only point of view from which empirical knowledge is less crude depends on the amount of relevant research that has been made. Much more has become known about malaria and syphilis, about quinine and mercury, about dropsy and digitalis, about energy and electrons. But to him who confronts a choice of the

next step, the situation contains elements of crudity which he recognizes as not far removed from that of that predecessor of his, who took the adventurous first step. So long as there are further steps there is adventure and so long as there is adventure there is crudity. Otherwise research would be a commonplace procession along the avenues of the known. The Lindberghs would be the last to underestimate the Nungessers.

He who tells us we must halt a research until analysis has proceeded further must be certain of a number of matters around which this discussion has taken place. He must know that further analysis of a complex situation is rewarding. A chemist preparing therapeutic agents will appreciate this point. Suppose it were optochin he had prepared and were told that too frequently giving his preparation caused blindness. Against pneumococci his agent worked admirably—that was his original objective. To perfect his agent and to safeguard it against unexpected, unfortunate consequences, what must he do? Must he search for other substances, similar in structure, must he try another group of agents, or must he, by analyzing optochin further, hope to discover what is offending in the structure of his drug at a different lower level of organization?

Quinine and quinidine afford another example. The auricles, the entrance chambers in the hearts of human beings, often lose their custom of orderly contraction and do what we call, fibrillate—a state in which they live and act but do so in a very disorderly fashion. A sufferer from this disorder once noticed that frequently when he took quinine, the normal behavior of his heart was restored. He narrated his experience to his physician in Vienna, Professor Wenckebach. Professor Wenckebach sought to repeat his patient's attempts but met with scant success— and told his story in one of his treatises. It occurred to another physician—Frey—to try more or less systematically other chemical substances with which quinine is related. At this point it becomes necessary, perhaps unwarrantedly, to assume certain biographical details. Was that a rational procedure of Frey's—was there good reason to think other quinine-like substances would work better than quinine; if so, which one, related how to quinine? Or should he explore other substances—not quinine but substances belonging to that series? Or should he attempt to build up quinine into a drug more complex? Or should he break it down to find what in quinine actually worked in Professor Wenckebach's patient—purify the drug in short? Or should he look for a substance which, in Professor Wenckebach's patient, aided quinine but was absent in his own? Or did his own patient harbor a substance which interferred with the action of quinine? All these were possibilities. A complete account of how Frey behaved in this situation is unknown—it usually is. He may have tried none of these or many. He had a single guide only. He was told quinine worked in a *single* person. We are speaking of levels of organization. The only point of immediate concern is whether he should have analyzed further to find a simpler substance. It may be, he should have done so, for the result of his labors has been effective in about 60 per cent. only of patients. In that sense the problem is still open and the various choices enumerated for investigation still available. What Frey did was to explore what is possible on the very level of organization of quinine sulphate. He found in the group a substance which worked 60 per cent. of the time, quinidine sulphate, identical with quinine sulphate except for its action on polarized light. This was turned left—quinine turns it right. The structural formula symbolizes the difference in that the two are written as mirror images of each other. In this case, no further analytical procedures were undertaken. Success, partial, it is true, came on a

level of organization no different from before. There was no way of knowing beforehand that this would be the case. Attention to causation would not have helped. It was not known, it is not known now, what causally is essential in this reaction. It is therefore unprofitable to search for it.

It is in the nature of things that students of any phenomenon must have first-hand knowledge of that phenomenon itself. For simple description first-hand acquaintance is all that is requisite. For analysis it is essential in addition, to possess knowledge of the art and practice of appropriate forms of analysis. There is no fundamental difference in the nature of these procedures for students of diseases and for other natural scientists. Nor is there a difference in the operations which the mind undertakes. The intellectual powers appropriate to elucidation of the two are the same, whether the object of study is a disease or an electron. The physical methods employed in laboratories naturally differ and are especially adapted to the objectives and material being analyzed. But the mind proceeds always in the same way; it knows few tricks and these few it employs indifferently wherever it has use for them. The mental act, when it comes to procedure, measures, indifferent to rational objective, length or volume or frequency. The behavior of the mind remains always the same irrespective of the tools it causes to be used in the various situations in which it acts—it describes, it classifies, it dissects. Experience must come first and then the analysis of that experience, whatever the object.

But a potential difference exists nevertheless. The practice of medicine is an ancient calling. It is as intricate as it is ancient. It is one of the nicest of the arts. Its practitioners have been in the habit of performing many social functions. These have been so absorbing that until almost contemporary time neither leisure nor opportunity nor perhaps desire was available to proceed beyond simple description, of which there has been much, to analysis[10] which has but recently, and let us hope not tentatively, begun. What needs appreciating is that the gap between practice and analyzing is by way of being bridged. The existence of the gap can not be ignored. Of its deterring effect much has been made—in my judgment much too much. When students were inadequately, or not at all, trained for research, more weight attached to the exclusive demands of practice than now. Much has changed, not least the estimate placed on traditional knowledge and on practical legerdemain, though medical opinion still insists upon transmitting a great deal of this in formal education. But in spite of all change, of persons interested in diseases, two types can be seen to emerge, one interested in advancing knowledge about them, and the other in treating them. The difference is similar to that between engineers and physicists. Physicians who wish to learn how to analyze, now can do so—and do so to extraordinarily useful purpose. But there is the difficulty I have mentioned—the gap. It is real and it is important. It occasions a difference not found, I fancy to the same extent, in other sciences having both theoretical and practical phases. Who would suppose, for example, that Graves disease (exophthalmic goiter), in order properly to be comprehended requires knowledge of physiological occurrences and chemical processes, obviously not necessarily within the competent knowledge of conscientious practitioners of medicine? Or in the kind of cardiac affection common in older individuals, of insight into and control of the most intimate behavior of muscle fibers? And not only that, but knowledge of what underlies the behavior of those muscle fibers and their ability to carry on work. I have spoken of other difficulties which beset physicians, but here is a major one.

[10] Not psycho-analysis.

To treat what is so obviously wrong, he must have learned, in physiology and physics and chemistry, what a man can learn only, if he learn it at all, as the result of the expenditure of all his energy. Research, in these circumstances, was at an impasse. For 25 years and more the effort has been made to bridge this gap by providing opportunity for a few physicians at least, to free themselves from the demands of practice. The divorce of research from demands so continuously absorbing has accomplished noteworthy results. Whether the divorce is adequate has not, I think, received sufficient scrutiny.

This much can be said safely, that time for research has been gained. And this in addition that to concentrate effort, a certain amount of irrelevant information may be left at the wayside. And finally this, that physicians who observe the phenomena of diseases receive from their intimate contact with patients and their ailments, stimuli to ferret out the meaning of what they observe. No one else has access to that knowledge. Having that knowledge and requisite training, the hope is still entertained that physicians, specially chosen, can solve the relevant problems. It would be idle to underrate the difficulties. They do not so much consist in translating problems from bedside to laboratory as from transvaluing one pattern of knowledge with its technical (clinical) apparatus to another quite different pattern with equally exacting, if not more complicated, technical (mechanical) apparatus. To recognize, for example, a cardiac disease, to think of its origin, to study its future, is obviously a different enterprise from search for the mechanism of the contraction of muscle on which its clinical manifestations depend. For that search involves far away knowledge of proteins and the part they play in the complex structure of muscle, as a result of which they contract. Other illustrations may be chosen —syphilis for example, its dependence on a microorganism—a spirochete—and the susceptibility of spirochetes to poisoning by arsenical compounds. Or still another, diabetes mellitus, depending essentially on destruction or malfunction of a single structure in the pancreas—the islands of Langerhans—and its remediability on a substance extracted from these islands.

This discussion and these illustrations should suffice to define a peculiar situation in medical science. I have already spoken of a special characteristic of the subject matter of "medicine"—the absence of "enduringness" exhibited by diseases. And now I have added illustrations dealing with the apparently wide interval between diseases as natural phenomena and the cumbersome traditional technique for learning about them, the practical aspects of this study, on the one hand; and the equipment necessary to deal with the analytical procedures necessary in research, on the other, to explain how the position of medical science and of medical scientists has come to be somewhat different from that in other sciences and how the intellectual position of medical scientists has been regarded as differing from that of other scientists.

It is, I think, impossible just now to exaggerate from a public point of view the importance of treatment. The motives which have brought great funds for study into existence have not, except in connection with great dangers, arisen from general public interest. The year 1776 was remarkable, aside from having witnessed the signature of the Declaration of Independence, for the effort Johann Peter Frank made, on behalf of the Archbishop of Speyer, to gather information on a social, political, or at all events on a grand scale, concerning the health of a population, so as to make this more secure. That adventure began an epoch. Usually, it has been the illness of a friend or a member of a family that stimulated the insistent interest of private philanthropists. The universities

had no funds. Government took a minimum interest only.

Once, when I defined medicine as the study of *diseases,* Doctor Thayer objected vigorously because in his judgment, joined inseparably to the study of diseases was the need to get on with the business of curing these diseases. The term medicine, he thought, included both. Obviously a term can mean whatever we say that it does. There is no reason against the use of the term "medicine" in the manner on which Doctor Thayer insisted. It is preferable though, I think, not to make the meaning of terms too inclusive; that is a way of obscuring the variety of aspects which a situation can be made to disclose. It is undoubted, indeed in the world of medicine, the notion is widespread, that to search out the nature of diseases is one of our chief obligations. But there is no doubt also, that the notion of curing diseases is universally believed to be a function of physicians. The function of medicine in the *cure* of diseases is so deeply imbedded in both public and professional minds that there have been periods of impatience with the belief that the business of curing is difficult and complicated (Hahnemann, etc.); with those who insisted on an education more or less elaborate for men whose office it might become to search out cures. Joining the search for knowledge of diseases with curing has, I think, tended to obscure the problems presented by both. It is not without importance to point out that to make cures provides, within properly defined limits, for a kind of activity not encountered in other disciplines.

Cures are of two kinds—we have depended on what I have been calling "crude empiricism" for one of them. Here there is no use for the refinement of analytical procedures. Agents not rationally related to complaints are used to mitigate them. Such agents do turn up, as digitalis in the case of dropsy, suggested by a Shropshire housewife who interested the willing Doctor Withering in her experiences; or when, owing to faith in the providence of God, the notion is entertained that where diseases occur, there in close proximity are their cures to be found—as salicylic acid (the willow) in the case of rheumatic fever.

The other kind of cure relies on nothing so simple, nothing so fortuitous. In this case cures are conceived possible because of a belief that there exists something in a morbid condition, central to it, a knowledge of which would further the possibility of cure, as of microorganisms in typhoid fever; or of toxins in diphtheria; or excess activity of an organ, as in thyroid hyperactivity; or deficiency in a secretion, as in pernicious anaemia; or defect or destruction in tissues or organs, exerting either immediate or remote consequences, as the effect on the heart in beri-beri, or of the late result of rheumatic fever; or, following in the footsteps of Ponce de Leon, substances which neutralize the action of agents that make the body age.

But how are such substances to be found? There must be no mistake; they are actually and feverishly being sought. The sciences of chemo-therapy, physico-therapy, immunology, pharmacology, the founding of institutes for the study of cancer and for this, that, or that other, are evidence of the liveliness of the quest. Sometimes the direction of research is simple enough—the agents being already well known; in the case of haemolytic streptococcus infections, sulphanilamide; in tetanus, tetanus antitoxin; in the failure of cardiac muscle, digitalis. But in the case of cancer the situation is different; since neither cause nor cure is known, shall the search be for an agent to combat a virus or some other substance or for the correction of a constitutional arrangement responsible for the licentious growth? The direction which the search is to take is often the subject of sharp cleavages of opinion. The single subject, cancer, illustrates how in the

process of analysis, talents, equipments, trainings of different forms may become serviceable. If you believe cancer is caused by a virus you want men to search for it who are perhaps differently endowed and certainly differently equipped from men who believe the solution of this problem lies in discovering a chemical substance to be neutralized, responsible for its origin or development.

To a choice of means, beside haphazard, there is no other guide but reason. But reason operates in the domain of causation and its tool is logic informed by insight, which in an exact sense is experience in action. Now, as has long been evident, reason alone is inadequate. Hope resides in the use of reason to limit the region of investigation so that then, within narrow, indeed within the narrowest framework possible, systematic trial and error can be attempted. If science is empiric, somehow experience provides it with a pattern. That is Aristotelian. Here is the inescapable region for the display of scholarship, ingenuity, resource. What the issue is to be, in seeking the cause or cure of cancer, no one now, I presume, would be bold enough to declare. It is a fortunate circumstance that men of many minds, everywhere, are engaged in this search. But the point to be made is that once the method of crude empiricism is abandoned, the alternative, which is analysis, requires technical education not at the disposal of everyone interested in a subject. The problem is the problem of the physician as scientist. Special training is the price of analysis and analysis is the consequence of the failure of the obvious.

I could have drawn this lesson on rational therapeutics from another source. It has been said, and said plentifully, that the dawning interest in ailments of the aging is the result of social pressure. Formerly that pressure was exercised, as now in the case of poliomyelitis, to secure protection from bacterial diseases, because they, often being contagious, were dangerous and required quarantine. Comparable pressure is being exercised now because the ailments incident to older age are long drawn out and tend to be costly—indeed very costly. The study of statistics created awareness of this situation; deaths from certain causes were increasing. In the course of a few years a general conception of what this meant began to be clear—or clearer. Little was known. The study of aging began then in a more serious fashion.

The problem what and how to study is not, in some respects, unlike that in cancer. What causes aging? Is it necessary or preventable? If preventable, does it result from subtle injuries inflicted in the course of ordinary living—injuries due to infection or diet or to other environmental moments? Where is evidence to be sought? In changes in the arteries or in some other tissue or organ? Is its cause a substance secreted within the organism—constituting a master reaction—not by design, though that is not an unusual conception, but because of its fortuitous and unavoidable nature? If aging is the result of any of these causes, obviously means to bring the process to a standstill can conceivably be found. But if it should turn out that it is none of these or none comparable to them, that aging is universal, it will be necessary to turn to the notion that aging takes place in the nature of things, that somehow it is incident to living, an expression of the togetherness of the organism, not a follow the leader mechanism; that the disabilities and ailments to which it gives rise call for alleviation of disability and suffering, different—or perhaps not different—from those that are sought on the assumption of preventability.

From the point of view of research, the meaning is clear. The resources of intelligence are wanted badly in this situation—natural historians, statisticians, morphologists, chemists of several sorts, physiologists, physicians. There may be

short cuts to discoveries in this category, but the history of science does not encourage us to expect to find one. It is more likely that in order to learn what to do, it is necessary first to search out the forces that are at work, and the precise forms they assume. Attempts to anticipate solutions by short cuts have too often been futile. We are, naturally, not told that enough is known to make a solution possible. And then it is no longer believed widely that genius can advance far beyond current knowledge. Newton, for example, is unthinkable as a contemporary of Aristotle. Failure in scientific research is often the natural answer to premature adventure. The frequency of simultaneous discoveries is evidence for the correctness of this view. Pressing on the door of the unknown is nowadays constantly taking place. But we do not believe we know beforehand who will force an entrance. We believe, therefore, in freedom of research—one of the academic freedoms which ought accordingly, sedulously to be preserved. Whether a research can be made to pay is a matter of judgment. Who has this judgment? Experience counts of course, though the inexperienced, like Parsifal, often see the light. But Aristotle, Harvey, Young, Helmholtz, Pasteur, Hering, Ludwig, Gaskell, Darwin, to name only biologists, were not inexperienced. Since chance enters the calculation, there is little room for dogma.

The clinic has been an integral part in the scheme for providing for the care and study of patients and their ailments. The very fact that clinics present the opportunity of seeing and comparing the manifestations exhibited by patients has facilitated greatly, as Shryock has pointed out, the description and classification of diseases. To be able to do this is, as we now know, indispensable in the development of scientific knowledge. When the stage of analyzing the appearances of diseases is reached, the equipment possible to clinics is essential. Equipment includes, for example, laboratories for chemical analyses, for the study of the physiological and physical aspects of diseases, for bacteriology, serology, immunity, haematology. In the past 100 years, but more especially in the past 30, such opportunities have actually been provided on a fair scale. It has become possible for physicians to study whatever phase of a disease seems important. Naturally clinics do not neglect the management of patients. On the contrary. They exist for the sole purpose of encouraging better and proper treatment, as adequate as contemporary knowledge permits. It is illuminating to observe how quickly the general public has learned to find its way to university clinics in the belief that the latest information on the cure of diseases is to be found there, where the search for their causes and nature is actively going on. The fear, once entertained, that patients dread examinations by students and are unwilling to subject themselves to novel procedures even though undertaken with proper precautions has been found not to exist or to have been much exaggerated. How to carry on clinical research is one of the lessons which has been learned.

Now, what can be successfully undertaken in the way of research in clinics depends on several factors. It is obvious that the subjects for research are diseases which the patients in a clinic present—these being presumably representative of the forms of illness present in a community. Certain illnesses can be profitably studied—others not. It would for example have been futile for Borelli or for von Helmont in the 17th and 18th centuries to study infectious diseases. Underlying and contributory knowledge was not yet available.

In the choice of subjects, what I have been calling the level of organization counts—and counts heavily. A distinguished biologist of the past generation spoke often to his friends of the uselessness of investigating diseases until more

was known about the behavior of cells, the ultimate proximate constituents composing animals and plants. In certain directions his view was undoubtedly sound. But sera, like those used successfully in treating certain pneumonias or in diphtheria; or a drug like quinidine; or bacteria as causes of diseases; or fibrillation of the auricles as underlying a striking disorder of the heart beat—all these can be, have been, and are being studied to the great benefit of man without carrying on the investigation at a level of organization much below that on which the going concern which is the organism, carries on. It goes without saying that every analysis occurs on a level simpler than that of the thing analyzed. That is in the inescapable nature of analysis. But how far below? I have been saying, not very far, because relevant knowledge is usually not available—and in the solution of a problem, a level too far below may cease to be relevant. In analyzing morbid processes, the opportunity should be available to carry on an investigation at that level precisely, where an experienced or an especially gifted person decides it may be profitable.

Objection is raised on occasion to affording this opportunity in clinics, the point being that that opportunity should be sought elsewhere either because elsewhere the cost, financially, may be less; or because the inclusion elsewhere of that research may be more appropriate; or because historically there is value in retaining that study at the locus of its origin. But this is a workaday world; it is difficult to get things done anywhere; men carry on, each his own business and do that with difficulty and against odds. Answers are sought because they are needed. Pathological anatomists, for example, are often in despair because of the lacunae, of great importance to them, left by anatomists. The situation is exactly similar when clinicians require information not supplied by physiologists. But even if anatomists and physiologists have developed a subject, there can be no obligation upon them to go on with it. They may not be aware of the need of a next step. To those to whom taking it is necessary, it is scant comfort to know where preliminary investigations were carried on, if they are no longer being housed there. The fructification of ideas can not be shackled to a building or even to a locality. But even if the study of a subject is duplicated, the loss is usually not great. Identity in result is rare, mutual criticism is profitable, slight differences in procedure are desirable.

There must of course be some sort of common sense on what is investigated in clinics; no one now would regard it as sensible to establish a laboratory for the study of electrons. But such researches as on the metabolism of bacteria, on nomograms describing acid-base and other equilibria, the location and behavior of salts and water, the mechanism of respiratory ferments and no doubt a host of others seem to be appropriate. To afford hospitality in clinics for such studies seems wholly reasonable. So will domiciling other activities, when the principles involved are scrutinized and understood, such as describing long drawn out diseases and senescent states, especially when the interest in them is peculiar to the clinic, and the emphasis necessarily different from that outside.

The question finally arises as to whether men exist in clinics willing to devote themselves to investigations at fundamental levels. Though enterprises at such levels are relatively new, it appears already that little or no difficulty is being experienced. If there is difficulty it exists perhaps in the temptation to draw to too practical purposes, the labors of those who should be studying at simpler levels. But if so-called fundamental researches are fostered, there exists the possibility of guiding them within pragmatic limits, and of acquainting clinicians with the value of such enterprises. Against the cost, if the cost

is high, must be balanced the motives, the interest in, the concern for the subject. It seems too theoretical to expel from clinics what can be done there profitably, especially when a clinical interest meets with no outside echo. There are things, it seems, more expensive than money.

The discussion on the nature of the medical clinic has not, I believe, these many years past, given due place to these more general aspects of its life. Primary attention was focussed on practice and on teaching because they seemed to be more urgent. These three, teaching, practice and research can, of course, be conducted as coordinate functions. The devotion to practice and to teaching must in no sense be whittled away. But it will not be, if the experience of recent years is a guide. What is wanted is a realization that in university clinics, all scholars need not be cut according to the same pattern. Traditionally the roles of teacher and practitioner have been emphasized—perhaps overemphasized. But a clinic affords opportunity for the display of diverse talents; there can be doubt no longer that men of diverse talents can find happiness and opportunity there. To arrive at the precise specifications should not, within this framework, be too difficult. If the conviction begins to prevail that these various functions should find their home there, their adjustment and accommodation may safely be left to the slow, one would hope not too slow, processes of time.

The crucial point appears to be that, to succeed, research in medicine must be regarded a serious undertaking. For whatever reasons, the issues are now regarded as sufficiently urgent by the general public, so that government is devoting increasing attention to the health of the community. To take this problem seriously means that scholars in medicine must be permitted to be serious, as are those in other callings. Education and the equipment for research must of course be adequate. And the rewards for service must be ample. Free and frequent criticism must be cultivated. This has been sharp in a technological sense. Experimental nonsense is not lightly tolerated. From a more general point of view—that dealing with the purposes and direction of research, criticism seems to be less well informed. Criticism of a kind can be found in presidential addresses, but the vigor, insight and fearlessness displayed is perhaps not sufficently incisive.

This is what I understand the meaning of medical research to be. The study of diseases has been separated in a category somewhat different from that of the other sciences. That has been due in part to the nature of its subject matter, being in a limited sense, less enduring than that taken for analysis in the other sciences. It has been due in part also to the lateness with which analytical methods have been employed in the study of diseases. The use of them now is in full swing but, being new, the education of men eager to employ them has not been adequately conceived to this end. For this reason also, a critical approach to the analysis of diseases has not yet fully evolved.

Of the objects of human interest, diseases are far from the least. The need for getting on with the understanding of many maladies is urgent. These are very varied, and require for their elucidation professional insight and equipment of a high order. The problems are becoming not less, but more intricate, the more the methods of empiricism change from crude to less crude. The meaning of medical research is to understand the mechanisms at play and to be concerned with their alleviation and cure.

THE ENTOMOLOGIST AND HUMAN HEALTH

By S. MARCOVITCH

TENNESSEE AGRICULTURAL EXPERIMENT STATION

In the gay nineties the entomologist was pictured as a spectacled professor happily chasing butterflies with a huge net, quite oblivious to his surroundings. If some one with shrubbery or garden cared enough to consult him, this old gentleman could tell a story of the relation of that butterfly to the injury caused by worms on the plants. He was happy to think that the hours of ecstasy spent with his insects was not all selfish delight; and he was still happier if he could devise a remedy to save the potato crop from being completely chewed up by the potato bug, or free his cattle from the dreaded Texas fever tick.

In the last twenty-five years our insect foes have increased so enormously that a conservative estimate places the damage to our health, our crops and our houses, caused by insects in the United States, at not less than $2,200,000 a year. To stay the enemy, over 100,000,000 pounds of insecticides are now used annually, under the direction of entomologists. From an obscure bug chaser, the entomologist suddenly emerges as the most powerful dispenser of lethal poisons the world has known, making the work of the Chemical Warfare Service puny by comparison.

Just as suddenly, Messrs. Kallet and Schlink discovered that all fruits and vegetables are dosed with arsenic and lead and that thousands are dying because of government indifference. Because of failure to enforce the pure food laws, they consider the real rascals to be the Food and Drug officials. Since the numerous poisonings are not played up in the press, Mr. Schlink, with the zeal of a crusader, proceeds to tell us fearlessly that even their own words understate the true situation. "Six persons poisoned in California in 1931 by greens sprayed with lead arsenate. . . . A four-year-old Philadelphia girl dead in August, 1932, from eating sprayed fruit."

Now Mr. Schlink, being a trained engineer, does not ask that you take his word for it. Scientifically, he refers you to "the most thoroughgoing of recent investigations of arsenic poisoning" made by Dr. C. N. Meyers and Dr. Throne, of the New York Skin and Cancer Hospital. Their investigations have shown that arsenic was the factor causing "bald spots" and the increasing amount of baldness. Speaking of the high arsenic content of fish, Meyers reported in *Industrial and Engineering Chemistry* as follows: "It is well known that certain individuals are unable to eat fish, and that others can not eat certain varieties of fish. An examination of representative fish has shown that arsenic and lead are present in certain parts of these specimens. The values found show the relation of the use of insecticides for the purpose of destroying larvae: Man destroys the larvae; the fish eat the larvae; and man eats the fish." Meyers is also concerned for our birds, which are destroyed as a result of eating insects associated with the destruction of fruits and vegetables. In answer to this contention, F. E. Whitehead, of the Oklahoma Agricultural Experiment Station, has shown experimentally that there is no danger of humans being poisoned from eating chickens that have eaten poisoned grasshoppers.

Again, according to Schlink, "Farm animals are frequently poisoned by browsing under the orchard trees, or licking their branches. The meat and milk from affected farm animals is of course poisoned." With this as a clew, the prevailing and perplexing stomach

upsets seem to be easily explained and robbed of their mysterious origin. The exact cause of the intestinal disorders from which Barbara Stanwyck, Jean Parker and Margaret Lindsay suffered is now thought to be poison sprays used on vegetables. The pictures of the famous screen actresses appeared in the newspapers and started a wide-spread inspection of fruits and vegetables at markets. In the absence of known causes, such gastrointestinal symptoms, in the opinion of medical experts, arouse suspicion of lead and arsenic. On the other hand, H. C. Sherman states that defective sanitation of food due to bacteria may result in serious cases of poisoning. "Sanitation is the means of prevention of all such impairments of health by food."

Dr. Hanzlik, of Stanford University School of Medicine, analyzed cabbage sprayed with lead arsenate and found .02 to .45 grain of arsenic per pound, and concludes that "one or two grains of arsenic may be toxic or fatal to an adult." As long as Dr. Hanzlik and others confine themselves to the *chronic* effects of arsenic and lead on fruits, they are safe, for no one has the evidence to refute them; but when reference is made to fatal doses, they are confusing the issue, for the strengths of fatal doses are well known. Text-books on pharmacology are not interested in lead arsenate but in Fowler's solution used as a tonic. A fatal dose of arsenic trioxide dissolved as Fowler's solution is 5 milligrams per kilogram of body weight. The relatively insoluble lead arsenate, however, has a toxicity of 500 milligrams per kilogram of body weight. In other words, white arsenic is 100 times as toxic as lead arsenate. To be scientific, we must designate the compound we are dealing with. The same error is made by Mr. Schlink, from whom we quote as follows: "The decision of the Food and Drug Administration to permit permanently a residue of 1/100 of a grain of arsenic trioxide in each pound of fruit. . . ." Here again arsenic trioxide is confused with lead arsenate. A poison to be most effective must be soluble. The well-known and insoluble barium sulphate swallowed in x-ray studies is non-toxic, while the same material as soluble barium chloride would be fatal. The famous Manchester outbreak of arsenical poisoning in beer was also caused by white arsenic in solution and not by lead arsenate.

We will leave the determination of the effects of arsenic and lead on fruits to the U. S. Public Health Service, which is now engaged in its study. Meanwhile, arsenical substitutes containing fluorine have been developed, such as cryolite. In 1932 this insecticide appeared to be the ideal material; then a report appeared from Arizona showing that mottled enamel of the teeth was caused in that state by fluorine dissolved in the water supplies when obtained from wells. The Food and Drug officials immediately imposed a tolerance on fluorine of .01 of a grain per pound of fruit, or 1.4 parts per million. Since the scope of knowledge was restricted, they believed that fluorine could not be more toxic than arsenic. Once again a chemical in solution was confused with a relatively insoluble material, such as cryolite.

For the past two years the Tennessee Agricultural Experiment Station has been engaged in a study of the toxicity of fluorine as it occurs in drinking water, with the toxicity of cryolite ingested in the quantities involved in the spray-residue problem. The details of this report are available in bulletin form, and only a few of the most significant findings will be mentioned here. When fluorine occurs in the water supply, more fluorine may be swallowed through the process of cooking than through drinking. Water is consumed in greater quantities than all other substances ingested, especially during the summer months. Assuming that 10 per cent. of our fruits and vegetables

are sprayed, the consumption of water is 30 times as great as that of sprayed food. Teakettle scale from a mottled-enamel area was found to contain 8,072 parts per million of fluorine.

Marine foods such as salmon, sardines, and baby foods prepared with bone meal (endorsed by the American Medical Association) contain up to 12 parts per million of fluorine; yet mottled enamel has been produced by no other means in the United States than the continued ingestion of water containing toxic amounts of dissolved fluorides during the period of calcification (between birth and eight years of age) of the crowns of the permanent teeth. The situation is aptly stated by Dean, of the Public Health Service, as follows: "In the light of present knowledge mottled enamel is a waterborne disease associated with the ingestion of toxic amounts of fluoride present in the water used for drinking and cooking during the period of tooth calcification." The present tolerance on fluorine is, therefore, a standard for water supplies and has little or no relation to our spray-residue situation.

Another important advantage of cryolite is that it is incapable of causing fatalities, regardless of the dose consumed, and that it is a much safer material than lead arsenate, being less than one per cent. as toxic to human beings.

In order that a broad view of the situation may be had, the problem of the insect menace deserves consideration. Few people not directly concerned realize the constant and relentless warfare that the agriculturist must wage against hordes of injurious insects in order to arrest their remarkable productivity. The apple is said to have as many as 500 species of insect enemies. Long before the fragrant pink apple blossoms make their appearance, a battle has been waged against the San Jose scale by means of oil sprays. With the resumption of growth in the spring, the tree is beset by lice, caterpillars, weevils, worms, bugs, and numerous other pests. To aid him in his efforts to preserve our food supply, the farmer looks to the entomologist. If the orchardist offers wormy apples for sale, he is practicing adulteration by adding a material to the apple. Whether or not an added material in minute quantities is deleterious to health is difficult to prove legally. And so it seems that in a society whose economic and social forces are delicately poised, we must choose between a small, malformed apple, inhabited and adulterated by worms, and a large, well-colored, appetizing apple, which contains minute traces of material added for its preservation. In the final analysis, we have no choice in the matter. We must protect the fruit and the vegetable if we would preserve our own bodies. We must fight off the insect menace which threatens to take possession of our food supplies.

ON FOOT THROUGH TANGANYIKA

By MARIUS FORTIE
MILANO, ITALY

I

On Tuesday, June 6, 1933, I started from Arusha, a small town near Mount Meru in the Kilimanjaro Massif, three degrees south of the equator, in Tanganyika Territory, East Africa, with a safari of twenty-one porters, one guide and three servants—all natives. The word safari means a journey on foot and with porters. It also indicates the travelers themselves and the loads. The main purpose of my safari was to trace African and Asiatic friends not seen or heard from since 1906, when I had left the land after a sojourn of five years, during which I had gone almost African, living close to the natives, loving them and speaking their language with youthful spirit and relish. I had gone back in 1907, and again in 1917, spending altogether more than twelve years among the Bantu, and incurring natural obligations which belated conscience pangs bade me discharge in 1933. I also purposed to observe changes in native life, and the spread of the Swahili language during the last thirty years.

With the exception of the provinces of Ruanda and Urundi, mandated to Belgium, Tanganyika Territory covers all pre-war German East Africa and is administered by Great Britain under mandate from the League of Nations. It is a strictly tropical country unfit for white settlement, bounded by the Indian Ocean, Kenya Colony and, roughly, by the three great fresh-water lakes, Nyanza, Tanganyika and Nyasa. It has an area nearly five times that of Great Britain; a native population of more than 5,000,000; about 10,000 whites and 30,000 Asiatics, mostly Arabs and Hindus from British India.

The natives are nearly all Bantu Negroes on a fairly uniform level of culture, speaking a variety of vernaculars dominated by Swahili, the great Bantu-Arabic *lingua franca* of equatorial Africa, used and understood by fifty million Africans, and said to gain one million a year. Although Tanganyika has some towns, the vast majority of the natives are small peasant farmers and cattlemen living in bush villages practically as they did a thousand years ago when the Arabs began to reach the Zanzibar coast and to penetrate the interior with their reckless safaris.

Tanganyika has a few railroads, and a system of so-called motor roads seldom passable in the rainy season. My objectives compelled me to travel on foot by the old-fashioned safari which must keep close to water and rations. Hence, usually I followed the native trails which lead from hut to hut, from village to village, and are kinder and cooler than the government roads to bare feet. My two safaris of 1933 and 1934 covered more than 3,600 miles, averaging thirteen miles a day, but marching frequently as much as thirty miles between camps. My aim was to go over the route of the safaris of my youth, and to revisit about two hundred bush villages in the vast area between the Great Lakes.

With plenty of time available, and the dry season just beginning, I was not tied to a particular itinerary, but followed a generally westerly trend toward Tabora. The Masai still hold much of the country between Arusha and Mbulu. A few are taking to agriculture, but the

TWO OF THE AUTHOR'S PORTERS

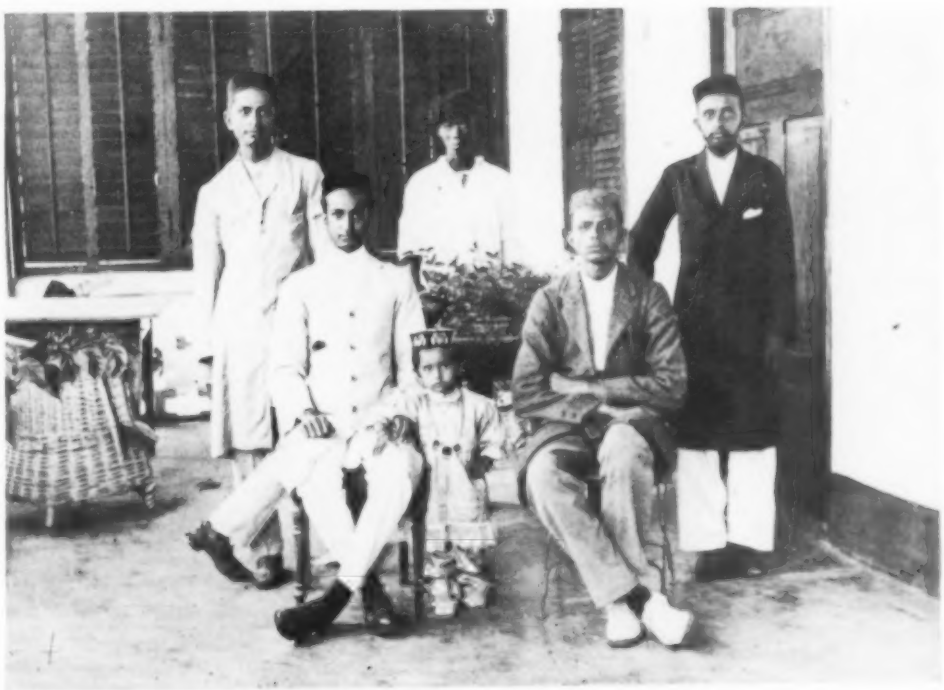
bulk graze their cattle as of yore on the slopes, in the bowls and basins of a mountainous district to heights exceeding nine thousand feet above sea level. Milk was plentiful and there was no lack of game for meat, but my porters often went without their rations of corn and millet meal. Water was scarce and bad. There were no fruits or vegetables, and it was too early in the year for the wild fruits of the bush. As almost everywhere else in Tanganyika, I found growing near habitations a sort of dandelion (*Sonchus bipontini?*) called by the natives *mchunga* or *msunga* because of its bitter taste. Mixed with the likewise common purslane, it made a tasty and wholesome green salad.

I crossed the alkali desert of Engaruka on the night of June 11–12, and rested for two days at the oasis of the same name, a Bantu settlement established by the Germans as a model agricultural village and police outpost in Masailand. There seemed to be much sickness among the people, and a physician from Goa made a good living. Here, as elsewhere in the colony, the natives flocked to my tent to be doctored for common ailments, skin, eye and lung diseases, and nowhere did I find them in possession of really valuable remedies. Sensational statements have been made, great hopes have been aroused regarding plants of wonderful medicinal value in Tanganyika. I saw no foundation for such statements or hopes.

On the way to Ngorongoro Crater, one of the great shows on our planet, we had to surmount steep stony trails over high mountains with chilly fogs in the morning and freezing temperature at night. On June 19, at an elevation approaching 9,000 feet, the tent fly froze stiff and could not be folded till four hours after sunrise. That same day we had an almost sudden drop of three thousand feet into the crater, which swarmed with zebras, gnus, kongoni and other species of antelopes. Ngorongoro Crater is a game preserve with high fees for limited hunting licenses.

Climbing out of the crater through dense rain forest, I took the trail to Mbulu through a region of typical savanna, where systematical deforestation was carried out by the government in an effort to check the tsetse fly, which spreads sleeping sickness among humans and animals. All efforts, however, are merely experimental. There was no evidence that the work done had any effect on the incidence of the calamitous fly, whereas it was evident that the insect liked to travel by train, automobile and airplane, and was thus carried rapidly to areas where it had never occurred before.

WOMEN OF BUSH VILLAGE SELLING YAMS



EAST AFRICAN HINDUS

PITCHING CAMP AMID MILLET FIELDS

Six marches from Mbulu the country began to flatten out into plains dotted with the granite formations met all the way to Tabora right into Lake Victoria at Mwanza. The light forest abounded in plants yielding edible fruits, nuts, berries and tubers. The *mfuu* (*Vitex cuneata*) was common and welcome to all. It is a handsome tree producing black fruits ranging in size from an olive to a walnut. The pulp is mealy and sweet, the stone woody. Days later we found near Tabora a clump of trees bearing fruits as large as plums, but not as palatable as the smaller variety.

I planned to reach Tabora cutting through a depression of the Vembere Steppe crossed more than once in my youth, but upon reaching Ushora, a village of rustling doom palms forty miles out of Singida, I heard that several natives had disappeared in bottomless ooze while following the trail I had in mind. So the safari made a detour to the right. We crossed the northern tip of the steppe, floundering through a mile of black mire, then were chased by tsetse flies over many miles of elephant grass, thorny mimosa and waterless light forest without settlements. On July 19, we had to camp in the bush without water.

There occurs frequently in that region a tree which I have not been able to identify, called *mbungu* by the natives of Unyamwezi. It sends out long roots, horizontally, like pipes, less than two feet from the surface. A four-inch root will run several feet without tapering, then branch off with two slightly smaller roots which will likewise run many feet without a taper, branch off into smaller roots, and so on. The roots are flexible, like lead. A six-foot length of four-inch root, held perpendicular, will drip almost a pint of cool water, clear and wholesome. My porters found

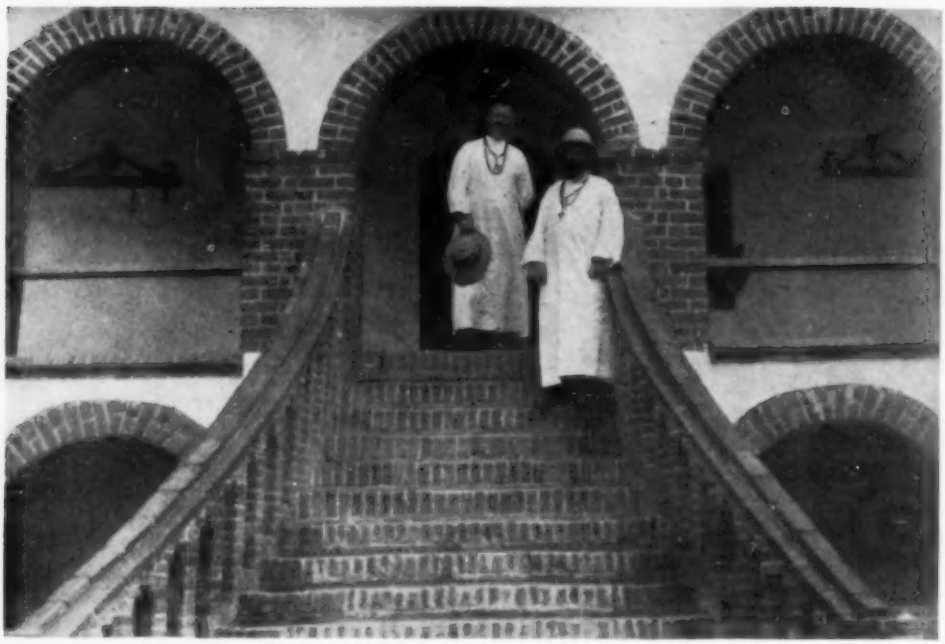
several *mbungu* trees, also two vines, arm-thick, that yielded wholesome water.

The light forest abounded with trees bearing edible fruits, some of which seemed to me of great promise if cultivated and improved. Although I found it harsh, my men ate freely of a beautiful apple-like fruit called *mgongo* (*Sclerocarya caffra?*), also many varieties of *Strychnos*, some of which I relished. I saw many small trees of the wild custard apple (*Anona senegalensis*), all bearing delicious fruit. The tree resists bush fires and, if improved, might easily become as valuable to native and colonist as the apple in the West.

Emerging from the waterless bush, we entered a settled region with extensive fields of corn, millet, yam, cassava, peanuts. Although water seemed scarce, the landscape had a green and prosperous look. Normally the rainfall is sufficient for agricultural and pastoral purposes nearly everywhere in Tanganyika, but the natives have yet to be taught the rudiments of irrigation and water conservancy. It is lack of water for domestic purposes that prevents native settlement of large areas, of which the government has deprived the native under pretext that he makes no use of them. Many such areas, declared crown lands, have been given, leased or sold to immigrants, white and Asiatic, for pastures and plantations, and costly mistakes have been made in cattle, rubber, cotton, sisal, tea, coffee.

On the morning of July 25, we halted under the imposing fortress which the Germans built in the '90s on a hill commanding the famous Arab-Swahili town of Tabora. It is now overwhelmingly Hindu, as is the important port of Mwanza on Lake Victoria, reached on

A MUHIMA CHIEF OF RUANDA



FRENCH FATHERS AT KAREMA

August 14, over the level, thrifty land of Usukuma inhabited by one of the finest and most progressive Bantu groups in Tanganyika. Gold, both alluvial and reef, coal, tin, diamonds and other minerals have been located in this district, also in widely scattered areas elsewhere in the colony. It seems that the entire granite-ribbed plateau within the three Great Lakes must be considered highly mineralized. The gold fields of Musoma on Lake Victoria, those of Sekenke and Singida, and especially those of the Lupa basin near Lake Rukwa, have already taken a prominent place in the economy of the land, with growing disastrous effects on native life.

In the meantime, after an absence of thirty years, I found no advance in the economy of the bush villages. Under compulsion, under the pressure of taxation in cash, the natives raise with varying success cash crops such as peanuts, cotton, coffee, tobacco. But not a single food crop, not a fruit, not a vegetable, not a domestic animal has been added to the village economy. Year in and year out, the natives of many districts eat for months on end only a mush of millet or corn meal, with relishes of boiled weeds, grasshoppers or termites. Meat and fish are rare treats, legumes are scarce and soon weeviled, and there is a general lack of fats in the diet because, as a rule, the entire peanut crop must be sold to the Hindus to provide tax money.

I remained a week in Mwanza to reorganize the safari and plan the next lap to Ruanda and Lake Kivu. After turning the Emin Pasha Gulf, we entered a region, extending through Ruanda into Uganda, where plantains and kidney beans are the staff of life. The green plantains are peeled with a bamboo knife and steamed in earthen pots with fresh banana leaves and little water. The beans are cooked separately and require hours of boiling. Salt is added liberally to the plantains during the cooking. When done, the whole is dished out on

green leaves, and I found it nourishing and palatable fare. The beans are considered a relish, and so are grasshoppers, termites, certain tree caterpillars and mosquito-like gnats, a pest on the Victoria Nyanza. They neither bite nor sting, but drift with the monsoon in dense banks, often smothering fishermen to death in their canoes. At night the gnats are collected in great quantities near lights and fires, and are pounded into hard loaves and cakes as nutritious and lasting as pemmican, but not nearly so palatable to a white man.

Our trails were strewn with the hard shells of edible *Strychnos* and with the stones of the *mbula*, a fruit of which we ate a great deal. It is borne by several species of *Parinum* (*P. curatellefolium*, *P. excelsum*, *P. macrophyllum*), large handsome trees with pinkish blossoms, yielding a close-grained wood of light color, fine for cabinet work. The fruit, in size from a plum to a goose egg, has yellow meat, mealy, sweet, nourishing. The woody stone contains seeds of fine flavor, raw or roasted. I often saw before the huts mounds of cracked *Parinum* stones, but never a tree that looked as though it had been intentionally planted. Yet this beautiful and valuable tree is common in the bush. I saw it growing, but bearing harsh fruit, to considerable elevations in the Livingstone Mountains. Selection and domestication would surely make it one of the most useful trees in East Africa.

On September 11, five marches west of Biharamulo, I pitched my ninety-eighth camp on a bluff overlooking the junction of the Ruvuvu and Kagera rivers, within hearing of the Rusumu Falls, down which tumbled a great volume of water. We ferried in leaky canoes into Ruanda, now under Belgian mandate, where, owing to the lack of an $8 consular visa, I was compelled to give up the march to Lake Kivu and to reenter Tanganyika

A WITCH DANCE

for a safari of twenty-five days to Ujiji. We tramped over Keza, Kibondo and Kasulu through one of the worst sleeping-sickness belts in Africa. There the government carried out on a large scale what, in the present state of knowledge, seems an effective remedy: it was moving 18,000 native families to new land. I saw everywhere abandoned villages, fallow fields, lines of natives straggling to new settlements or concentration camps, where the Franco-Algerian White Fathers are a great help in a great need.

From Kasulu, a picturesque fortress of German days, we dropped in forty-five miles from a high of 6,000 to a low of 2,560 feet, the present level of Lake Tanganyika, entering the rolling lake region of sandy loam with great fields of cassava and, almost suddenly, the trees beloved of the coast Swahili: papaya, mango, date, coco and oil palm. Although still a large settlement, Ujiji is now less important than Kigoma, a new

THE AUTHOR'S KITCHEN DEVIL AT TUKUYU

town at the terminal of the Central Railway. Here my porters found in overabundance the delights for which they had yearned through fifty hard marches since leaving Mwanza, and the safari went to pieces. With difficulty I managed to keep a nucleus of ten men and to place them on board the steamer *Liemba*, which sailed south the night of October 16. Three days afterward we landed at Kipili, below the old French mission of Karema, and, with additional porters furnished by the government, began the march to Kasanga and Abercorn through Ufipa.

Ufipa presented a Bantu culture older, more developed, more resistant to change, hence considered more backward by impatient and unsympathetic observers. Instead of the isolated huts and small villages common in the Tanganyika bush, here were towns of several streets lined with rectangular thatched dwellings built substantially of logs, plastered with clay, often whitewashed. The streets swarmed with children unclad, unwashed —the poor hop-a-back babies grimy bundles smothered with flies. Because of the tsetse, goats and sheep are the only live stock, though there is a plenty of chickens and dogs. The fields and gardens were in distant valleys or river bottoms, and I saw old granaries, or silos, of hard termite clay scattered through the wilderness.

That told me why the Tanganyika Bantu still exhibits behaviors greatly at variance with changed conditions: the conditions have changed recently, the behaviors are rooted in a past reaching back thousands of years. Until thirty years ago, Ufipa was exposed to the raids of the predatory Wangoni and Matabele. The Matabele chief Uzwangendaba is buried at Chapota, near Kasanga. So the Wafipa built their villages five, ten miles from the fields, hid their stores of food in the wilderness, and when the raiders came gave up their dwellings and

WASOKIRE NATIVES OF TUKUYU

fled to the bush. An African village of sticks, mud and straw is easily rebuilt if the population can save its provisions.

That told me likewise why the Tanganyika Bantu is interested only in his few standard crops; why he plants no fruit trees, or trees of any kind. In the past his village has been constantly on the move for two main reasons. In the first place he did not practice crop rotation. He tilled an area to exhaustion, then brought a piece of virgin land under the hoe, moving his village to remain reasonably near his fields. In the second place, warfare, raids, feuds often drove thousands from their homes overnight and forever. Villages might also be abandoned on account of drought, fire, unremitting crop failures, vermin, lions, sickness, witchcraft. As a result, which persists as a racial trait down into the present time of relative stability and security, the native will not undertake works of a far-flung or permanent character that may interfere with a sudden move, or make it too bitter, too regrettable. He plants no trees, digs no permanent wells, builds no substantial dwellings or shrines. It is only when faced by necessity that a native community will undertake extensive jobs of irrigation against drought or of fencing against pigs and other vermin. Thus when the family, the clan, the tribe or the nation moves, nothing lasting is left behind, and in a few years almost all traces of human occupation disappear.

I found Ufipa in the grip of a disastrous locust invasion. Almost the only food available at some camps were heaps of the unsavory insects dried and sauté. The usual fare of the people is a gritty mush of *Eleusine coracana* eaten with a relish of mushrooms, boiled beans, termites or grasshoppers. Game is rather scarce and the live stock seldom slaughtered for food. Vying with children and baboons, I eked out my provisions with the fruits of several species of *Strychnos* trees common in Ufipa.

After leaving Kasanga, the Bismarckburg of German days, a camp was pitched on the brink of the Kalambo Falls, said to be the highest in Africa. There is a single sheer drop of more than 700 feet, twice the height of the Victoria Falls, and more than four times that of Niagara Falls. From Abercorn we struck across Northern Rhodesia toward Karonga, on Lake Nyasa, touching Isoka, the Fife of some maps. Disease and homesickness had reduced to seven the experienced porters of the old gang, and I had to recruit from village to village local men who gave no end of trouble. The three hundred miles to Karonga, covered in sixteen days, were exceedingly hard. The long marches were made more difficult by the bush fires that burned every blade of grass and singed every tree from river bottoms to mountain peaks.

On reaching Karonga on Lake Nyasa nearly every porter deserted, and so did my cook. A small steamboat took me to Mwaya in Tanganyika, where I was able to organize another safari for Tukuyu, the Neu-Langenburg of the Germans, a pleasant place of pines and eucalypti 6,000 feet up in the hills. The rain-clouds were now rolling up from the south, and I saw that my safari must soon come to an end. A reluctant column of local natives carried my loads in four days from Tukuyu to Mbeya through the mists and storms of the chill Igali Pass, reaching Mbeya on December 7, 1933, 185 days and 2,150 miles from Arusha.

Mbeya had become a small town of some importance owing to the Lupa gold fields thirty miles away, which for several years have yielded considerable amounts of alluvial gold. Some reefs were being brought into production, and many optimists predicted the development of another Rand. From fifteen to twenty thousand natives worked all year in the diggings, mainly to earn tax money, with a huge labor turn-over affecting many tribes in Tanganyika, Northern Rhodesia and Nyasaland. Giving way to the demands of the white miners, the government, though pledged under the terms of the mandate to consider the interests of the natives paramount, placed those natives under restrictions of increasing severity, tending to reproduce the appalling conditions existing among the native population in the Union of South Africa.

Great Britain could easily interpret her mandate in Tanganyika in a high and generous spirit of true stewardship. She grants the more progressive tribes—that is to say those that pay taxes readily and buy much Western trash—what is officially styled Indirect Rule, a meager measure of self-government in petty local affairs, provided they be conducted in approved British manner. But the pressure of taxation in cash, the deposition of the native chiefs, the disintegration of Bantu society through missionary propaganda and money economy, cause a growing tendency of the able-bodied male population to leave the tribal villages for town, plantation and mine. Many never return. In a village of 54 huts I found only seventeen able-bodied adult males. The huts were ruinous, the fields neglected, the children untaught and wayward, the women dissatisfied and debauched. In the words of Akeley, the darkest chapters in Bantu history are being written now under the white man's rule.

II

With the big rains approaching, no porters could be found in Mbeya. I was forced to go to Dodoma by truck, then by train to Dar es Salaam, the capital, where I stayed until June awaiting fair weather. On June 21, 1934, I left Dar es Salaam with a safari of twenty-four natives, planning to reach Lake Nyasa and the Livingstone Mountains by way

of Mahenge, Songea and Manda. As the belated rains had continued beyond the normal period, the first three weeks were full of anxiety and hardships for the safari. I had so much trouble with porters sickening and running away, that it was only at Kidodi, nineteen marches from Dar es Salaam, that the safari fell into stride.

A magnificent and appalling wilderness swallowed us up three marches from the coast. Soggy patches of grass ten feet high and ten miles across; mazes of elephant tracks; morasses pitted by the hippos that came up every night from the Ruvu River; gloomy rain-forests where the guides often stuck fast in perplexity, asking counsel of the white man who had hired them for counsel. On July 9, somehow, we emerged at Kidodi on the Kilosa-Mahenge road still deep in mud, still impassable to motor traffic. But it seemed excellent to us and we made good progress toward Mahenge.

In all this region were vast abandoned plantations of Ceara rubber trees (*Manihot glaziovii*), which formed impenetrable jungles where was light forest and savanna thirty years before. On July 14, we reached the large village of Ifakara on the Kilombero River, which it took the safari three hours to cross by wading and canoeing. Excellent rice and fish go from Ifakara to many Tanganyika markets down the Kilombero and Rufiji rivers. I saw here many fine specimens of *Telfairia pedata*, a vine of the cucurbit family called *kweme* in Swahili. It is frequently found associated with the *mvule* (*Chlorophora excelsa*), an immense tree that furnishes beautiful hard wood, termite proof, but liable to dry rot. The *kweme* vine, often more than a foot across, climbs up to a hundred feet and more, the plant spreading over the crown of the tree and producing a profusion of pumpkin-like fruits that weigh up to sixty pounds.

THE NATIVE QUARTER OF DAR ES SALAAM

STARTING A FIRE IN A BUSH CAMP

The bitter, unedible pulp contains from a hundred to three hundred flat seeds two inches and more across. The kernels, roasted, have a rich nutty flavor and yield a sweet oil as good as that of the olive.

Mahenge, 3,400 feet above sea level, was reached on July 17, twenty-seven days and 360 miles out of Dar es Salaam. The next 280 miles to Songea, covered in seventeen days, proved easy and pleasant on the whole, although troubles and difficulties were not lacking. Villages were so few and far apart that I pitched several camps in the bush. In one of those camps a porter dug up a quantity of tubers of a kind he had eaten before, and which I was not able to identify. With some of his mates, he roasted and ate them, and the meal made every one sick. That astonished the digger very much, because he knew his tubers and was quite sure they were edible. He was probably right, but the plant may have been a *Solanum* whose tubers, as happens with Irish potatoes, may occasionally be poisonous.

Fifteen miles south of Songea, reached on August 5, I camped in the grounds of Peramiho Mission, an immense abbey, the mother of many more throughout the region down to Lake Nyasa. Those missions build substantially of brick and stone; they have chapels, hospitals, schools; tailor, carpenter and shoemaker shops; flour and oil mills; forges, brick kilns, great orchards and vegetable gardens, stables with cattle and hogs of good breeds. From Peramiho we entered Umatengo, and during five days we marched through beautiful mountain landscapes reminiscent of the Tyrol. The Wamatengo terrace with their fields the steepest hills to their summits, practice irrigation, and in the villages they bring a brooklet to every dwelling. Among the usual millet and corn were fields of green peas, wheat and Irish potatoes, with patches of coffee in favored spots.

The nights were exceedingly cold in the gorges of Umatengo. At the mission of Litembo, nearly 6,000 feet above sea level, my thermometer fell to fifty degrees immediately after sunset, and hovered around forty all night. Only two days afterward we were on the shores of Lake Nyasa, camped amid huge baobabs, plagued by mosquitoes and heat. We skirted the lake for three days with many detours on account of streams and sheer bluffs, and ferried the Ruhuhu River in two ancient canoes, one of which capsized in a crocodile scare. Manda, big on most maps, had only a dingy post office and two native shops without provisions for me or rations for my men. Thus it was with light loads that the safari began to climb the Livingstone Mountains on August 21.

The level of Lake Nyasa is 1,645 feet. The ten days it took us to reach the government post of Njombe in the Poroto Range were a series of difficult climbs and drops between 8,000 and 5,000 feet, with Njombe at 6,300. It being winter, we met with severe weather everywhere: heavy fogs, chill gales, rain and painfully cold nights. The region had a curious non-African appearance. More than once I was startled by the almost naked Negroes cowering in an icy drizzle around smoky embers before squalid huts, half stable, half dwelling. I would have thought it more natural to find Swiss chalets and yodeling mountaineers.

The only staple food I could get for my porters was a mixture of corn and kidney beans, dried, which were boiled together and so eaten with some wretched relish such as boiled yam tops. There was scarcely any game, the natives did not willingly part with their few chickens, sheep or goats, and the bush offered little to eat on those high levels. Trees of *Parinum* were common, but the fruit was too harsh to eat. In the neighborhood of Njombe I saw the Cape gooseberry (*Physalis edulis*) grow wild in profusion, also many species of *Rubus*, but none in bearing.

After Njombe my porters would have no more rain-swept mountains and polar nights. Hastening through Ubena, a region that had not yet recovered from the barbarous punishment received in the rebellion of 1906 against the Germans, we dropped into Usango, a land of sunshine and plenty. For the first time since leaving the coast, we saw here great herds of cattle, and my camps overflowed with the eatables beloved of the Bantu. One tenth of a shilling bought a gallon of sweet milk and enough millet beer to cripple the safari. The general prosperity found expression in gay cottons and in much drunkenness—the Bantu's only dissipation and solace.

The level plains of Usango ended at the Usafu escarpment, which took us up into the Lupa plateau and the gold fields. At the first camp on the diggings, pitched in a gale on September 12, my safari of twenty men had two bottles of sour milk and a hatful of finger-thick yams for rations, and no water—famine and thirst amid the gold pits, with plenty in Usango a few miles below. But the bush yielded a deal of two unidentified fruits called *sungwi* and *masuka*. Although hardly a food, they whiled away hunger on the march and between naps.

I rested two days in Chunya, a new government mining post, where I was able to give my hungry men corn meal rations in lieu of the daily fifth of a shilling which had been the rule on this safari and on the previous one. Water was so scarce that in many cases watercarriers could make only two trips in twelve hours between wells and mining camps. Hence little mining was done, and that mostly by blowing. The native sifted the alluvial dirt in an iron pan, sorted out the coarse stuff, then blew off the residue until, perchance, a little gold was

A MISSION SCHOOL

left. The best panners were the Wasokire of Tukuyu, canny Bantu who were learning the value of gold much too fast to suit the greed of their white masters. With restrictions and penalties of increasing severity, the government tried to make gold worthless to the blacks and worth more to the whites.

Hurrying toward Lake Rukwa to exchange fresh fish for the now palling game and birds, we followed trails through light forests of leafless straight

CORAL BEACH NEAR DAR ES SALAAM

trees, the ground extensively dug up by prospectors all the way to the Lupa River. Some sluicing was going on at water holes by the river bed, but all signs of prospecting ceased on the right bank. During the next six days, however, we heard the rumble of blasting from the hills on our right. British companies were developing promising gold reefs, a modern mining town was rising at Saza, a few miles above Lake Rukwa, where half a million pounds was being spent.

Our first camp on Lake Rukwa was pitched on September 19. No shooting is permitted within five miles of the shores, but Lake Rukwa is a vague geographical expression in which five miles may mean as little as five inches. Before 1904, the name applied to a body of water about twenty miles long and ten miles across which expanded more than fifty miles to the northwest in one rainy season, and still covers at least three times the area shown on most maps. I found heavy canoes fully two miles from the water, and was assured that the lake would come up and float them in January.

Lake Rukwa is shallow; perhaps nowhere more than twenty feet deep. The turbid water, so charged with soda carbonate as to be hardly drinkable, teems with excellent fish. Catfish attain the size of a man. The shores are mostly flat and marshy, but in places granite bluffs rise sheer from the water and force the traveler to long detours over the hills. Immense flocks of white pelicans and other water birds float in banks offshore or wheel overhead, hippos splash and blow in the reeds, fresh elephant tracks crisscross the trails and dry river beds. Plump hyrax dwell among the boulders and are easily caught near the tamarinds, of whose pods they are fond. There is plenty of bigger game, also of spur geese, ducks, guineas, francolins and large species of pigeons.

But the mosquito and the tsetse fly gave us no peace in that beautiful region —indeed the tsetse chased us relentlessly day and night to the gates of Tabora. Moreover, the Lake Rukwa basin is now suspected of being one of the main breeding grounds of the calamitous grasshopper, the red locust. On September 23, the first day of spring in that latitude, I left Rukwa on the three-hundred-mile lap to Tabora. The safari was held together by eleven porters of the original gang from the coast, and by the fact that I walked every inch of the trail, sharing hardships and dangers. At Kitunda I put the almost mutinous group on a truck that took us to Sikonge, where the march was resumed to end at Tabora four days later, October 7, 1934—108 days and 1,600 miles from Dar es Salaam. After disbanding the safari, I went into camp in the Unyamwezi bush till March, 1935, to avoid returning to America in winter.

III

In the course of this article I have mentioned native wild plants of potential economic importance as foods, which were often a godsend to my porters and to me. Those plants are totally ignored by the immigrants, European and Asian. The government, the missions, the colonists make great efforts to introduce and keep going in Tanganyika plants that, with few exceptions, don't like to grow there. European fruits and vegetables and so-called colonial or tax crops—cotton, sisal, coffee, tea, tobacco—absorb all the attention, none being paid to the numerous plants of economic value native to the land, because their improvement and development would benefit mainly the Negro and bring no quick cash returns to the colonist.

Taxation in cash and other measures compel the Tanganyika native to raise cash crops for export, but the huge abandoned plantations of sisal, rubber,

tea, coffee and cotton prove that the system does the native and the land little permanent good. While shiploads of cotton and cotton seed leave Tanganyika to compete unfairly with the product of more progressive countries, the majority of Tanganyika's five million natives wear only loincloths or skins. While shiploads of peanuts and sesame leave Tanganyika to put the Mediterranean olive growers out of business, the native diet is so lacking in fats that cod and shark liver oils are currently administered in native schools and dispensaries. While the Tanganyika bush is occasionally searched for plants that may do well in Wales, California or Arizona, but usually won't, nobody searches the Tanganyika bush for plants that will do well in Tanganyika itself.

If a botanical expedition went to Tanganyika with the specific aim of studying wild plants of food value for improvement and domestication in Tanganyika, there would be no fear of failure. It would not have to be admitted years afterward, as a noted American botanist admits in a recent letter to me: "There are great thickets of wild fruit trees in Tanganyika, and although I introduced a good many in this country, I believe we have succeeded in establishing only one." It is in Tanganyika in the first place that wild Tanganyika fruit trees should be domesticated and improved to furnish the native more palatable and more nourishing fruit, and more of it, than is now the case with the wild trees, and to teach the native what the West knows of the art. Varieties would almost certainly be developed more apt to do well in America or Europe than the chance-picked wild plants that have failed so far. That can be said of all the fruits I have mentioned; of many more I have eaten and seen eaten by the natives; and of many awaiting discovery and intelligent survey in the bush.

AGING VERSUS INFIRMITY

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BIOLOGICAL change must not be confused with chronological time. We note the former only when its speed is great against a background of the latter as in the growth of childhood, the ravages of disease and the progress of infirmity.

In practice we can distinguish between the program of healthy growth and the progress of disease in childhood because, though both show vigorous change, the type of change is clearly constructive in the one and equally clearly destructive in the other.

Infirmity is not easily noted in childhood because there is nothing unequivocally destructive about it. The child is not ill. He may not be growing as vigorously as his brothers did. He may not be maturing quite so rapidly. Perhaps he is not doing so well at school. His infancy may have been one long struggle to find a dietary suitable to his digestion; his preschool period may have been marked by roughness or dryness of the skin, even by eczema in the folds, by recurrent obstinate "colds," and punctuated by the necessity of removing tonsils and adenoids and correction of visual defects. The grade-school stage may bring out defects of social adjustment at school or home, a high strung nature or a proneness to fatigue with headaches in the afternoon, disinclination for breakfast, stuffy nose in the mornings or an obstinate inability to put on weight. But the doctor pronounces his organs sound; the parents remember that one or both showed the same characteristics in their childhood but, notwithstanding this, they have grown up to be useful and efficient members of society. And so we prate about the infinite variability in human beings and, with fatalistic indifference, delude ourselves that all is really well with the child or, at worst, acknowledge that he is sensitive, subject to nightmares or hay fever, a little delicate, one of Pharaoh's lean cattle, fickle in appetite or averse to active games with other children. We employ a host of rationalizations to hide from ourselves the fact which nature strives to bring home to us that infirmity has its grip upon the child and is handicapping his enjoyment of life.

All physicians are by training pathologists who seek for definite clinical evidence of clear-cut disease and, finding it not, reassure us that this is something the child will outgrow, even as we, his parents, have outgrown similar minor troubles. The man who is forever engaged in treating sickness sooner or later loses sight of health. For him health is the absence of demonstrable disease, not something that sparkles in the eye, glows in the cheek, gives spirit and zest to the day's occupation and radiates through all human relationships. So our standard of health deteriorates and we juggle with abstract theories of what is optimum in growth, vigor, alertness and staying power.

Let me take as an example the life histories of three young guinea pigs from our colony in the nutritional study of the Associated Foundations. Each of these represents the typical progress of its group. One group we deprived of certain nutritionals, namely, vitamins B, E and C, one of B and E but gave a minimum of C, a third of B and E alone.

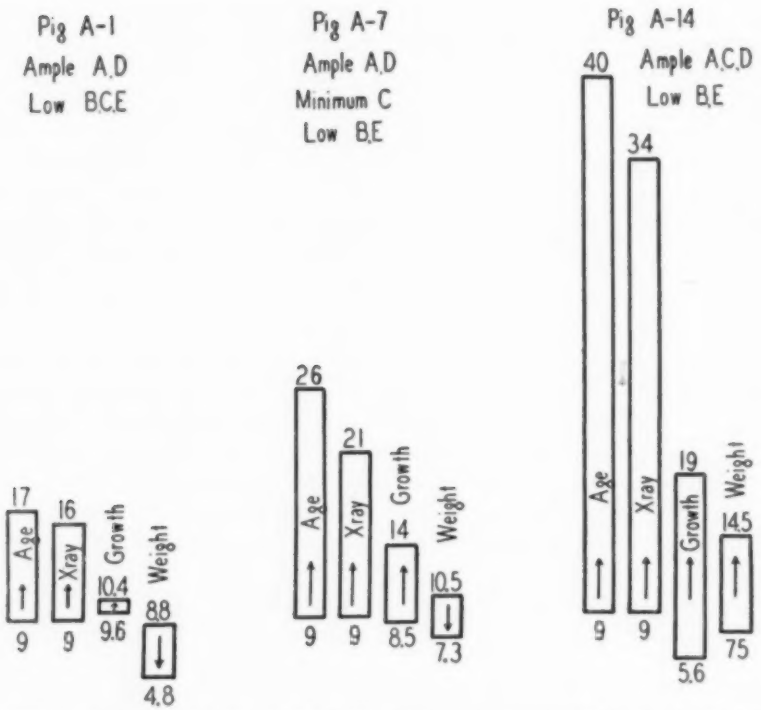

FIG. 1. TYPICAL REGISTERS OF DEVELOPMENTAL PROGRESS. GUINEA PIGS DEPRIVED OF CERTAIN NUTRITIONALS (FROM UNPUBLISHED WORK BY COHEN AND TODD). FOR FULL EXPLANATION SEE TEXT. A–14 REPRESENTS IN EXAGGERATED FASHION THE INFLUENCE OF DEFECTIVE NUTRITION IN CHILDREN.

The results are not directly traceable to simple deprivation of these essential elements of nutrition, but to the general metabolic disturbance initiated by the malnutrition (Fig. 1). The group of pig A–1 quickly succumbed; that of pig A–7 lived three months or so under the treatment and then died; pig A–14 lived six months or more, grew and put on weight, it is true, but was never robust and finally died from intercurrent disease to which its resistance was lowered by infirmity. The experiment, for which Dr. Milton B. Cohen was jointly responsible with myself, was started when the animals were nine weeks old. The columns in Fig. 1 register respectively in equivalents of chronological time the bone length (growth in dimension), physical maturity and weight of each animal at the beginning of the experiment and at its close in death. Where, as in A–1 and A–7, the disturbance of health was profound, weight fell off and growth was retarded, though maturation was not greatly inhibited. But in A–14 weight did not actually fall away. Weight, growth and maturation rate all were laggard, but maturation rate stuck most closely to the schedule based on the records of the healthy colony. This is the pig which most clearly illustrates my contention for infirmity in the young. Until the time when we abjure the comfortable, misleading doctrine of meaningless variations we shall not recognize the earmarks of infirmity. We must cease to rely upon standards of progress

in stature and in weight based on the great majority, especially upon those who are at or near the poverty line. The register of increment in height and weight must be checked against meticulous analytic studies of well children, longitudinal studies of children observed throughout their childhood and showing in their successful adaptation to food, to fortunate domestic circumstances and to their fellows a healthfulness for which all strive but few attain.[1]

I have spoken of maturation as distinct from growth. It is essential to grasp the significance of this distinction. A child not only grows; he grows up. The evidence of his growing up is recorded in his skeleton representing that part of the body which is clothed with skin without and supports the organs within. The skeletal register of maturation can be read by roentgenographic methods, a new branch of biological science only recently applied either to man[2] or animals[3]. Infirmity in childhood is recognized in many ways by those whose rationalization has not engendered an indifference to depreciation of the standards of health. It is chiefly obvious in failure to maintain that vigorous even progress in weight, in stature and in maturation which is characteristically apparent in a well selected group of really healthy children such as those to which allusion has been made in footnotes 1 and 2.

In middle life and still more in advanced age the changes characteristic of aging are so slow as to be almost unnoticeable, whereas those of disease or infirmity maintain their usual velocity. We distinguish the more rapacious disease from the less virulent infirmity but confuse the latter with aging of which we do not mark the evidence.

Aging is a process of adaptation both in structure and function. Structural adaptations are almost all completed by thirty years in man, but functional adaptations continue to be made. The impact of environment is met by changes in the organism. We call these respectively injury and repair. Aging in its functional aspect is therefore a continual repetition of injury and repair with repair dominant. By this physical experience we increase our tolerance, our resistance or, if you will, our immunity. Aging is the opposite of infirmity. But if something occurs to weaken the response to injury, aging is replaced by infirmity, since injury gains the upper hand in its struggle with repair.

This resistance against infection and toxic processes is developed in what we used to call the connective tissues of the body, a large part of which lies just under the skin. It is here indeed that the by-products of fatigue collect until they can be excreted. Hence the puffiness of the face in fatigue. As a matter of fact the subcutaneous connective tissue of the face illustrates very well the effect of repeated injury and repair. In the baby at birth the skin is not adherent to deeper structures at all. But in consequence of repeated puffiness and restoration there develops a scar tissue which by the time adult life is attained binds the skin to the deeper structures. A mask-like countenance with the wiping out of character by obliteration of the creases of health is the sign manual of weariness, infirmity or disease at all ages.

I have mentioned a definite upward limit to structural change. This occurs at different ages for different tissues. The child's brain is almost adult in form by the sixth birthday, his skeleton by the

[1] K. Simmons and T. W. Todd, *Growth*. In press. 1938.

[2] T. W. Todd, "Atlas of skeletal maturation." Part I—Hand. St. Louis, Mosby. 202 pp. 1937.

[3] Theodore T. Zuck, *Anat. Rec.*, 70: 389–399, 1938.

twentieth, his heart and muscles by the twenty-fifth. Nature is quite insistent on upward limits. After the whistle blows tools must down: another task must be undertaken. If the whistle blows before the task is completed tools must down just the same and structural incompleteness remains throughout life. This occasionally, though rarely, makes for weakness in defense or response because structural compensation usually provides against disaster. By its indomitable bias towards structural compensation, even after there has been marked interference with growth or maturation, the body makes an effort to readjust through enhanced growth or modification of proportions in the damaged area, always provided the damage done is not so great that the readaptation becomes impossible. The face is again a good example for, though its general lines are determined by heredity, the details of architecture in nasal form, jaw size and facial contour are modeled by fluctuations in bodily health.[4,5,6,7,8,9]

Structure, however, is merely the obvious expression of function. There must also, therefore, be upward limits of function. We do not know these well. In a man of sixty years a wound takes five times as many days to heal as a wound of the same size does in a child of ten.[10] Different tissues have different rates of dwindling in their power of response. Most of our organs are geared to last our time. Functional adaptation may dwindle or cease in skin, hair, teeth and nails without disturbing the rest of the body. But between skin without and the organs within is the body itself which obeys the will. It is this part of ourselves of which we are most acutely conscious, on whose health and power of repair we most depend. The tired business man is the tyrant of the family circle. As the heart goes with the muscles which it dominates, the brain goes with the body it directs. Whereas the body reaches adult size and maturity by about twenty years the heart is not fully mature till about twenty-five.[11] Hence the muscular system reaches its full power between twenty-five and thirty years, which is the age of sport championships in baseball, amateur golf, indoor tennis, boxing and marksmanship. The championship in outdoor tennis averages a little younger and that in golf a little older but not significantly so.[12,13] In industry as in sport the age of maximum efficiency immediately precedes thirty years.[14,15] The strength of a man of twenty-five years bears the same proportion to that of a man of sixty-five as the strength of the man of twenty-five bears to the strength of a woman of the same age in the same occupation. The upward limit in functional adaptation of the muscular system is determined, not in the muscles themselves, but in the cerebellum which coordinates muscular action. Ellis[16,17] showed that shortly

[4] L. Dewey Anderson, *Angle Orthodontist*, 7: 142–149, 1937.

[5] B. Holly Broadbent, *Angle Orthodontist*, 7: 193–208, 1937.

[6] Milton B. Cohen, *Angle Orthodontist*, 7: 150–154, 1937.

[7] Carl C. Francis, *Angle Orthodontist*, 7: 138–141, 1937.

[8] T. W. Todd, *Angle Orthodontist*, 7: 131–137, 1937.

[9] Theodore T. Zuck, *Angle Orthodontist*, 7: 155–157, 1937.

[10] P. Lecomte Du Noüy, "Biological Time." New York: Macmillan. 180 pp. See pp. 154–155. 1937.

[11] W. Erlich and A. E. Cohn, *Am. Jour. Anat.*, 49: pp. 209–240, 1931.

[12] H. C. Lehman, *Abst. in Psych. Bull.*, 34: 764–765, 1937.

[13] H. C. Lehman, *Sci. News Letter*, 32: 181, 1937.

[14] W. A. Schochrin, *Arbeitsphysiol.*, Bd. 8, S. 607–609, 1935.

[15] J. M. Ufland, *Arbeitsphysiol.*, Bd. 6, S. 653–663, 1933.

[16] R. S. Ellis, *Jour. Comp. Neurol.*, 30: 229–252, 1919.

[17] R. S. Ellis, *Jour. Comp. Neurol.*, 32: 1–33, 1920.

after thirty years there commence degenerative processes in the cells of the cerebellum which control muscular power and speed. The factor which modulates the vigor of response is found not in the instrument of that vigor but in the governor itself.

This is the cardinal theme of life in advancing years to-day. The statistical evaluation of our destiny is of comparatively little import. That, out of twenty adult men and women, five must die of cardiovascular disease, three of respiratory involvement, two of cancer, one of violence and nine of other numerically less frequent maladies[18] is interesting, no doubt. But it has little meaning for us who live. We are not concerned with death which, as a natural process of elimination, provides that the withered leaves of autumn become the wet nurses of the spring. What is important to us is the fulness of our life, the joy of hopefulness and self-reliance, the health of mind and body which spell fortitude, control and tolerance, the spirit which seeks and seizes opportunity and revels in success. We see it all portrayed on the advertisements in the street cars and the illustrations in popular magazines. Do we feel it in ourselves as we set out for the office or the shop? Do we meet it at home in the evening when the frivolous activities or distracting occupations of the day have ceased to enliven hope and conceal our true feeling? If not, it matters little that we are assured of organic soundness: we have exchanged aging for infirmity: the warning that we might heed is already displayed: the storm signal is out which none but the doomed would affect to deny.

A new chapter will be written into medicine when the criteria of healthy aging replace those standards of youth which serve us to-day. We are told[19] there are so far no effective standards of malnutrition in childhood; they are still to be discovered. The truth is rather that no one criterion is all-inclusive, for it is not in the physical structure that we should expect to find objective evidence of the first deterioration of health, but in those morbid moods which tarnish the joy of living and particularly the irascibilities and impatience of fatigue.

Criteria of healthy aging are of necessity different from those of youth. Our elasticity and resilience are lessened by the honorable scars of resistance and repair. Our speed of reaction may be curtailed, though alertness and grace remain. Staying power is more readily diminished and creative imagination more easily curbed by fatigue. Nevertheless, the portents of disaster are the same throughout life.

Fatigue, apprehension, despondency, are the signals set to warn us when we must take steps to maintain constructive healthy aging and not fall into the clutch of infirmity. The very scaffolding of intellect gives way if its load of morale is overstrained. Intelligence, unhampered by bodily fatigue, can sort and sift. It possesses the power of imagination which enables it to visualize future possibilities and make a plan which, granted physical health, it delights to carry out. We are concerned by the tragedy of recognizable disease which cuts off a man before his time, but we should be infinitely more moved by the pathos of a tragedy which cripples seven out of every ten of the so-called healthy men and women who have docilely accepted the substitution of infirmity which they might have avoided for aging, which is their birthright.

[18] M. Lawrie, "Nature Hits Back." London: Methuen. 180 pp. See pp. 156–7. 1936.

[19] Kenneth Fraser, *Manchester Guardian Weekly*, 35: ii. May 17, 1935.

SUMMARY

(1) Biological change must not be confused with chronological time. We note the former only when its speed is great against a background of the latter, as in the growth of childhood, the ravages of disease and the progress of infirmity.

(2) In middle life and still more in advanced age the changes characteristic of aging are so slow as to be almost unnoticeable, whereas those of disease or infirmity maintain their usual velocity. We distinguish the more rapacious disease from the less virulent infirmity but confuse the latter with aging, of which we do not mark the evidence.

(3) Aging is a process of adaptation both in structure and function. Structural adaptations are almost all completed by thirty years in man, but functional adaptations continue to be made. The impact of environment is met by changes in the organism. We call these respectively injury and repair. Aging in its functional aspect is therefore a continual repetition of injury and repair with repair dominant. But if something occurs to weaken the response to injury, aging is replaced by infirmity, since injury gains the upper hand in its struggle with repair.

(4) Different tissues have different rates of dwindling in their power of response. Most of our organs are geared to last our time. Functional adaptation may dwindle or cease in skin, hair, teeth and nails without disturbing greatly the rest of the body. But between skin without and organs within is the body itself, which obeys the will. It is this part of ourselves of which we are most acutely conscious, on whose health and power of repair we most depend.

(5) Criteria of healthy aging are of necessity different from those of youth. Our elasticity and resilience are lessened by the honorable scars of resistance and repair. Our speed of reaction may be curtailed though alertness and grace remain. Staying power is more readily diminished and creative imagination more easily curbed by fatigue. Nevertheless, the portents of disaster are the same throughout life.

THE GENERAL FORMAL EDUCATION OF EMINENT MEN

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FROM many sources has come evidence that persons who stand out above their fellows in the degree of their social recognition are above the average of the general population in length and quality of education. And the same thing in general has been true of the corresponding class of historical personages, as well as the greatest geniuses. Such superiority is a corollary of superior economic and occupational rank of the parents of such persons and of the persons themselves, on the one hand, and of the superior ability to benefit by an education, on the other hand. The facts of superiority are contrary only to the conception of members and former members of the lower classes who believe that outstanding people as a class are able to climb to the top of the social scale and make great achievements without any guidance from other people. However, all students of eminence and leadership, even those who use the hereditary interpretation of the facts, admit that the self-educated person is more unusual than usual and that the highly educated man is the average rather than the exception, even among the persons of the highest historical importance.

Of the sources of educational influence in the broadest sense of that term, three stand out on which sufficient information exists for useful analysis. The first is informal education of the home, the second formal education in lower and higher schools, and the third special education of the order of professional training. The present article will be concerned with only the second of these types of educational background.

In the relative numbers of 185 great leaders who were educated in a variety of ways we have a rough indication of the importance of various sorts of education. These preeminent historical figures were among the one thousand most eminent persons of the last few centuries and included no living persons. Fifty-one received classical training, 102 (55.1 per cent) college or university training, nine received a "limited education," three received "no formal education," ten received "slight education," and ten were "self-educated." Only 13 were without formal education, compared to 172 who received some degree of education, or roughly a ratio of 13 to 1.[1] Compared to the educational advantages of the average citizen in the same period, the eminent men were very greatly superior, although the degree of superiority is not known in statistical terms.

Data from Havelock Ellis's study of British leaders are not entirely comparable to those mentioned, since Ellis included data on only those with university training. This one item, however, is in close agreement with the international data; 53 per cent.[2] compared with 55.1 per cent. It is of interest to note that Ellis's list included persons less eminent than those in the study by Cox.

Turning now to studies of contemporary notables, we have from "Who's Who in America," 1934–35, statistics on 29,389

[1] C. M. Cox, "The Early Mental Traits of Three Hundred Geniuses," Stanford University, 1926, *passim*.

[2] Havelock Ellis, "A Study of British Genius," Revised Edition, Boston, 1926, pp. 127–128. Maclean's study, mentioned by Ellis, revealed roughly comparable data.

individuals reporting educational background, of whom 74.7 per cent. were graduated from higher educational institutions, 86.5 per cent. had attended such institutions, and 92.8 per cent. had attended high schools or their equivalent.[3] Other studies of contemporary persons eminent in various occupations also show a close relationship between education and eminence. For example, Lott found that 43.5 per cent. of 1,178 Montana urban leaders were college graduates, 59 per cent. had attended college, and 76.5 per cent. had attended high school.[4] This study shows less relationship between education and prominence than was found in the other investigations, but that may be due in part to the recency of the settlement of Montana, which would probably put less premium upon formal education than would be true of the average state which has a longer history. Davies, on the contrary, found that a correlation coefficient of .98 best expressed the degree of relationship between college education and attainment of national distinction by persons listed in "Who's Who in America," 1912–13.[5]

Trends

The most complete data showing trends in the educational experience of eminent men are from "Who's Who in America" (Table I). The significant fact is the rapid increase in the proportion of college graduates since 1916, especially from 1923 to 1929. Before 1916 the proportion had varied between 57.4 and 61.4 per cent. College non-graduates have varied within limits of 15.5 and 11.6 throughout the thirty-five years covered by the data. The proportion who had no more than secondary education rose consistently from 1899 to 1910 and declined steadily after 1916. The proportion of those with only common school education declined after 1910 until 1928. The proportion of those who were self-educated rose to a peak in 1910 and declined to the lowest point in 1928, but 1903 was the year of second lowest number of those self-educated. Private educated declined in importance

TABLE I

Percentage of Persons Listed in "Who's Who in America" Reporting Different Types of Educational Background

Last educational status attained	Year							
	1899[a]	1901[a]	1903[a]	1910[a]	1916[b]	1922[c]	1928[d]	1934[e]
College graduation	58.2	61.4	57.4	57.9	59.2	63.7	74.3	74.7
College attendance without graduation	15.5	12.3	15.0	13.2	13.7	13.7	11.6	11.8
Total college attendance	73.7	73.7	72.4	71.1	72.9	77.4	85.9	86.5
Secondary education[f]	15.7	16.0	17.6	18.9	18.1	14.1	7.4	6.3
Common or Public School Education	10.6	10.3	10.0	10.0	9.0	8.5	6.7	7.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total Cases in Series.	6,024	7,838	11,119	15,518	20,115	22,075	26,758	29,389

[a] Data from "Who's Who in America," 1910–11, p. xxiii.
[b] "Who's Who in America," 1918–19, p. 26.
[c] "Who's Who in America," 1924–25, p. 26.
[d] "Who's Who in America," 1930–31, p. 22.
[e] "Who's Who in America," 1936–37, p. 18.
[f] Includes secondary, high school and normal school education. In earlier periods all normal school students were classed as persons having secondary education. In the 1928–29 and 1934–35 editions normal school students from accredited schools were classified with college and university students.

[3] "Who's Who in America," 1936–37, p. 18.

[4] E. H. Lott, "Rural Contributions to Urban Leadership in Montana," *Montana State College Agricultural Experiment Station Bulletin*, No. 262, 1932, p. 29.

[5] G. R. Davies, "A Statistical Study of the Influence of Environment," *The Quarterly Journal of the University of North Dakota*, 4, 1913–14, 226.

from the period of 1903, with the lowest proportion in 1928.[6]

Evidence from a study of prominent business men bears out this trend. Most of the older group of men studied by Taussig and Joslyn were not college men, while most of the youngest were. There was an almost perfectly regular increase in proportions of those who had college education, as the average age of the groups decreased. And there was a corresponding decrease in the proportions with no formal education, grammar school, and preparatory school education. Of the group from 50 to 54 years of age, 32.6 per cent. were college graduates, 46 per cent. had attended college, only .6 per cent had had no formal education, and only 26.8 per cent. had had no more than a grammar school education. Of those who were from 30 to 34 years of age, 43.7 per cent. were college graduates, 67.9 per cent. had attended college, .3 per cent. had had no formal education, and 10.9 per cent. had had no more than a grammar school education. In comparison, of those men who were 75 years of age and over, only 15 per cent. were college graduates, only 26.5 per cent. had attended college, 1.8 per cent. had had no formal education, and 39 per cent. had had no more than a grammar school education. Although due allowances were made for various factors that would account for the trend besides actual tendency for more business leaders to be college trained, the conclusion that a real trend was displayed was retained.[7]

[6] These statements are substantiated by data included in the various analyses of educational reports on "Who's Who in America" data already mentioned. The numbers were not given for 1934–35 and throughout have been so small that there was no need of including them in the tabulation. The self-educated were as follows: 1899–20, 1901–31, 1903–24, 1910–67, 1916–77, 1922–58, 1928–39. Figures for private education were: 1899–185, 1901–282, 1903–446, 1910–209, 1916–282, 1922–331, 1928–367.

[7] F. W. Taussig and C. S. Joslyn, "American Business Leaders," New York, 1932, pp. 163–166.

Evidence from the 1924–1925 "Who's Who in America" shows that the average age at graduation from college was below that for the general college graduate,[8] a fact even more important when one considers that the average age of college graduates to-day is probably somewhat smaller for all than it once was.

Nearing's study of 2,000 persons listed in "Who's Who in America, 1914–15, whom he considered to be representative of the "younger generation of American genius," revealed the fact that 77.4 per cent. had received a four-year college education, 86.9 per cent had attended college, and only 13.1 per cent. had had no college education.[9] This group would correspond roughly in year of birth to the later studies of educational origins of persons listed in "Who's Who in America." And there is little difference between Nearing's figure for those who had attended college for at least a short time (86.9) and the corresponding figure for the total number of persons in "Who's Who in America, 1934–35 (86.5 per cent.). The other figures for these two analyses are also very similar. This is not surprising since any person born before 1869, which was the earliest date of birth of cases included in Nearing's second study, would be nearly sixty-five years of age at the time of the publication of the 1934–35 edition of "Who's Who in America," which is more characteristic of the age of the rank and file of prominent Americans than the average age of those under forty-five years of age.

Further evidence of the same sort is available from "America's Young Men," the new biennial list of important men most of whom are under forty years of age. In the first edition (1934–35) 95.2 per cent. had attended college and 86.9

[8] J. S. Cleland, "Age of Graduation and Success in Life," *School and Society*, 21, 1925, 31–32.

[9] S. Nearing, "The Younger Generation of American Genius," SCIENTIFIC MONTHLY, 2, 1916, 54.

per cent. were college graduates, while in the second edition (1936–37) 97.3 per cent. had attended college and 88.3 per cent. were college graduates.[10] The trend toward perfect agreement between prominence and college education thus continues on in accordance with past developments. In view of the fact that Nearing's percentage for younger leaders with college education in 1914–15 was almost identical with that for all leaders twenty years later, it seems possible to predict that the "Who's Who in America" group in 1954–55 will be almost uniformly from a college background. This prediction at first glance does not appear to be as sound as one based on the younger persons (those under forty-five years of age) in "Who's Who in America," but the method of compilation of "America's Young Men" appears to be so comparable to that of "Who's Who in America" that the prediction seems justifiable.

Any interpretation of trends must take into account the trend toward increased college education in the United States. This trend for the United States from 1880 to 1920, which embraces part of the trends shown in the "Who's Who in America" data and in Taussig and Joslyn's data, was from 687 male college graduates per 100,000 males twenty-two years of age and over for 1880 to 1,137 in 1920.[11] This is an increase of more than 65 per cent., a figure considerably greater than the increase in the percentage of persons listed in "Who's Who in America" with college education, but at the same time considerably short of the rate of increase required to keep pace with the rate of increase of the college education of the subjects of Taussig and Joslyn's study accompanying the decrease in the age-range. The national trend toward more education is thus at least a partial explanation of the trend toward the possession of more formal education by prominent men of the present generation. But there is still an increase that must be accounted for in other ways, the most probable explanation being an accelerating educational selection in prominent positions, although there may be an actual increase in the influence of education upon the rise to positions of prominence.

[10] "America's Young Men," 1936–37, p. xiii.

[11] J. P. Shaw, "Statistics of College Graduates," *Quarterly Publication of the American Statistical Association*, 17, 1920–21, 337.

Sex, Education and Eminence

The most recent data available on the educational background of women listed in "Who's Who in America" indicate that a somewhat smaller percentage are college trained than is true of men. Only 52.0 per cent. of the 1,622 women on whom sufficient data were given were graduated from college and universities or their equivalents. An additional 19.1 per cent. attended college without graduating, making a total of 71.2 per cent. with some education in college,[12] compared with 74.7 per cent. graduates and 86.5 per cent. with some college training in the total "Who's Who in America" group. It is thus obvious that proportionately fewer of the most outstanding women have received college education than is true of men of the same degree of recognition.

For a somewhat larger number of women which included persons of a lower degree of social recognition than the "Who's Who in America" listing the percentage of college graduates was 64.2 and those with some college training was 81.9.[13] Thus women at a lower level of

[12] "Who's Who in America," 1936–37, p. 2704.

[13] "American Women," 1937–38, p. xxi. The percentages are not strictly comparable because the biographies with insufficient data were not eliminated from the latter group. The superiority of educational background of the less restrictive group was greater when total women college graduates and with some college education are related to total women in the lists. Of all women in "Who's Who in America," 1934–35, only 43.2 per cent. specified college graduation, and only 59.1 per cent. specified some attendance at a college or university.

social recognition are more similar to men of a given degree of recognition in degree of education than they are to women of the given degree of recognition. Stated another way, American women appear to exhibit an inverse relationship between degree of recognition and degree of education. In view of the change in educational background for the total Who's Who in America" group over a period of thirty-five years, it seems likely that the difference between the educational background of women of different levels of recognition will prove transitory and is largely due to age. One test of this hypothesis would be to study a sample of the women at any level of recognition in order to determine if there is an educational superiority for the younger generation, that is, for the group that will later, for the most part, constitute the women of highest recognition. The argument is based on Nearing's discovery that the younger persons in "Who's Who in America" had superior educational background to the older ones and a background very similar to the present "Who's Who in America" population.

Another study that would shed some light on the same question is a comparison of the education of the most eminent 2,000 men in the United States with that of the same 2,000 plus the next most eminent 4,000 men. This would give comparable figures in proportion to the male population of comparable age to those obtained from the women of "Who's Who in America" and the women of "America's Women." It should be expected on the basis of the age hypothesis mentioned above that the higher education for the most prominent persons of each sex would be less than that for the least prominent. If such a study should show less education for the more than for the less prominent men, this might be interpreted as evidence that college is of minor importance for social recognition. But evidence of such a sort would not be conclusive because of the differential opportunity and stimulation of the older and younger personages for college education. Not until this element of the changing educational situation is eliminated by the passage of time or by some means of statistical control, can such studies offer evidence on the importance of college education for eminence. This will be mentioned again later.

Trends in the education of eminent women are of great importance for any sound interpretation of sex differences in the education of the prominent. Data are by no means as complete as for the total group of eminent personages. In the 1901–02 edition of "Who's Who in America" only 15.5 per cent. of the women listed had graduated from colleges and universities,[14] compared with 59.1 per cent. for the total group. The figures were 23.8 per cent. for women[15] and 56.0 per cent for the total in 1903, compared with 52.0 per cent. for women[16] and 74.7 per cent. for the total in 1934. The total percentages with some college education are available for more of the intervening editions. In 1903 the figure for women was 32.3 per cent. compared with 69.8 per cent. for the total.[17] In 1920 the percentage for women was 58.5[18] and for the total in 1922 was 77.4. By 1930 the women had gained even more ground.

[14] Amanda C. Northrup, "The Successful Women of America," *Popular Science Monthly*, 64, 1904, 243.

[15] "Who's Who in America," 1903–05, p. xx. Percentages based on a distribution including self-education and private education. Cf. Table I.

[16] "Who's Who in America," 1936–37, p. 18.

[17] "Who's Who in America," 1903–05, p. xx. Cf. footnote 15, above.

[18] S. S. Visher and Gertrude Haverstock, "Who's Who Among American Women," SCIENTIFIC MONTHLY, 15, 1922, 447.

The percentage was 76.8[19] compared with 85.1 for the total in 1928. In the 1934–35 edition women with some college training declined in proportion to 71.2 per cent.[20] compared with 86.5 per cent. for the total. The upward trend for women has been very pronounced except in the last period, the ratio for college graduates changing from slightly more than 1 to 4 in 1901 to 1 to 1.4 in 1934. Correspondingly the ratio for those attending college changed from 1 to 2 in 1903 to 1 to 1.2 in 1934. The present difference between the sexes is not great and probably reflects the differential education of the sexes at the present time, just as the rapid change of ratios reflects the increasing tendency for women to obtain college education during the last 30 years.

Education and Chances for Eminence

Several well-known students of eminent men have placed the chances for eminence of those with college education at more than one hundred times as good as those who had not received such education. Davies in 1917 concluded that chances were 196 times as great for college graduates as for the person who had not graduated from college.[21] Clarke's data were interpreted to mean that even more chances for becoming eminent men of letters were possessed by college-trained than those not educated in colleges.[22] Other studies containing data on education can be similarly interpreted.

The reasoning in support of the statements of differential chances for recognition on the part of persons with a particular educational background is based on the ratio of college graduates (or persons with a particular educational background) listed in "Who's Who in America" (or some comparable list) to all college graduates living at a given time, as well as on the ratio of the persons not graduated from college but listed in "Who's Who in America" to all persons living at the same time who had not graduated from college. By use of some estimates made by Shaw concerning the number of surviving college graduates in the United States in 1900, 1910 and 1920,[23] together with educational data from "Who's Who in America" for comparable years (1899, 1910, and 1922) it is possible to supplement previously existing knowledge. Of the 164,485 college graduates surviving in 1900, a total of 3,508 were listed in "Who's Who in America," 1899–1900, or one to every 46.9. Subtracting the 164,485 college graduates from the total males above twenty years of age in the United States in 1900, a total of 21,705,463 is obtained. Of these persons 2,586 were listed in "Who's Who in America," 1899–1900, or a ratio of 1 to every 8,393.4. The ratio of these ratios, in other words, the relative chances of college graduates and persons not graduated from college for inclusion in "Who's Who in America" at the turn of the century, was 179 to 1 to the advantage of college graduates.[24]

[19] A study by Eva M. Pletsch, quoted in "Who's Who in America," 1932–33, p. 26. Also see Bertha Beach Tharp, "Relation of Education to Success of Eminent Women," Scientific Monthly, 37, 1933, 134–38.

[20] "Who's Who in America," 1936–37, p. 18.

[21] G. R. Davies, "Social Environment," Chicago, 1917, p. 113.

[22] E. L. Clarke, "American Men of Letters; Their Nature and Nurture," *Columbia University Studies*, 72, 1916. The statement is "several hundred times," p. 68, although no statistics in support are given.

[23] Shaw, *op. cit.*, p. 339.

[24] The ratios contain certain errors, because estimates of surviving college graduates had to be employed. The more serious errors arise from the following facts: 1. The number of surviving graduates was estimated on the assumption that college graduates have the same survival rate as the general population of the same age and sex. This is undoubtedly not correct, but the precise advantage of college graduates in survival rate is not known. 2. The "Who's Who in America" group, containing a small percentage of women (ranging between 6 and 9 per cent), was related to the male population of the country. 3. The age of college graduates was assumed to be 22 years and over in making the estimates of

Corresponding figures for both 1910 and 1920 were 160 to 1 (Table II). The resulting series for three decades is not long enough to indicate a trend on which much dependence can be placed, and there are no data on number of college graduates living later than 1920 yet available for the extension of such a series. that the advantage with the college graduate has been reduced. In other words, college education has been extended to increasing numbers of people who, because of the relatively large numbers in relation to the positions of the highest social importance, cannot hope to be entered in the list of the most out-

TABLE II

RELATIVE CHANCES OF COLLEGE GRADUATES AND ADULTS NOT GRADUATING FROM COLLEGE FOR INCLUSION IN "WHO'S WHO IN AMERICA," 1900, 1910, 1920

Year	No. College Graduates in "Who's Who in America"	No. not College Graduates in "Who's Who in America"	Year	Estimated No. of College Graduates Surviving[c]	Male Population 20 Years of Age and Over not College Graduates[d]	Ratio of College Graduates in "Who's Who in America" to Total College Graduates	Ratio of Those in "Who's Who in America" not College Graduates to Total Male Population 20 Years of Age and Over not College Graduates	Number of Chances of College Graduates to 1 Chance for Those not College Graduates of Being Listed in "Who's Who in America"
	1	2		3	4	5 (Column 3) / (Column 1)	6 (Column 4) / (Column 2)	7 (Column 6) / (Column 5)
1922–1923	14,055[a]	8,020[a]	1920	358,026	31,888,945	25.5	3,976.2	160
1910–1911	8,985[b]	6,633[b]	1910	233,957	27,664,566	26.0	4,170.7	160
1899–1900	3,508[b]	2,586[b]	1900	164,485	21,705,463	46.9	8,393.4	179

[a] "Who's Who in America, 1924–25, p. 26.
[b] "Who's Who in America, 1916–17, p. xxv.
[c] Shaw, *op. cit.*, p. 339.
[d] Population data from Census of 1920, vol. II, p. 154.

On the basis of college enrollment up to 1930, however, it is clear that college graduates have been increasing in proportion more rapidly than the combined increase in the number of persons listed in "Who's Who in America" and the increased percentage of "Who's Who in America" personages who are college graduates.[25] Consequently, it is certain standing persons unless that list is broadened. Again, such a trend signifies that college education does not mean as much for eminence as it once did in this country, unless the definition of eminence is extended to more people. This is in spite of the increasing percentage of persons listed in "Who's Who in America" who have college training. In spite of the decline, it is obvious that the advantage for the college graduate will remain very large for a long time, and can never entirely disappear under the present social and educational order. And it is also worth pointing out that social contribution is not always in pro-

surviving graduates, but population data included persons over 20 years of age. In spite of these shortcomings in the calculations, the resulting ratios are in all probability substantially correct, and the data presented below on other decades are directly comparable, although not perfectly accurate.

[25] With a total of approximately 38,000,000 males in the United States over 20 years of age in 1930, and approximately 7,000 persons in "Who's Who in America," 1928–29 who were not college graduates, compared with less than 20,000 college graduates in "Who's Who in America," in order to retain the ratio of 160 to 1, less than 700,000 living college graduates would be required. Such a figure is far too small in view of the total of more than 900,000 students enrolled each year from 1927 to 1930 and more than 90,000 graduates each year after 1925, in addition to surviving graduates of varying ages.

portion to the recognition that a man is accorded, which is to say that chances for social contribution remain and will remain after chances for attaining the highest rank and recognition have declined.

Summary and Interpretation

In summing up the data on the amount of education of eminent persons, four conclusions are most obvious. First, whether small lists of the most eminent world-historical figures, somewhat less restricted lists, or lists of contemporary notable persons of the United States are employed, a high degree of education has almost always been possessed by the prominent person, and also a degree superior to that possessed by the rest of the population. Second, trends toward more advanced education and away from lower limits of education and from self-education are quite clear-cut. And there is no indication that this stage has been completed. Third, at the present time there is only a small sex difference in the education of persons in "Who's Who in America. Men surpass women in the proportion who have attended college and in the percentage who did not have as much as a common school education. The college training of women in "Who's Who in America" has increased at a more rapid rate than has that of men. Fourth, a man with a college education has many more chances for eminence than one whose education was not extended beyond a lower level. The relative advantage appears to have declined and is likely to continue to decline for at least a short time into the future.

Although these conclusions for eminent persons in general indicate a close association between education and the attainment of eminence, it is still a question in the minds of many whether education is responsible in any way for eminence. The specific suggestion has been made that the association is based on a selective factor rather than the contribution from education to achievement and recognition. According to this interpretation people who obtain formal education at the college level—although the theory would apply at all levels of formal education—have certain qualities of mental capacity and personality as well as opportunity to go to college. These persons also have important qualifications for eminence; indeed, perhaps the qualifications that enable young people to acquire formal education are those that enable them to rise to positions of prominence. The result is that those who would most likely become eminent because of qualifications not due to formal education, *per se*, are those who are most likely to obtain that formal education, thus confusing the causal factors.[26] The education itself, according to this theory, contributes nothing but confusion to the analysis of causation.

At present there is very little evidence concerning the true explanation of the relationship discovered. Taussig and Joslyn argue that the presence of superior proportions of college men in the larger business organizations does not prove the positive effect of college education, because there is no positive evidence of the effect of general school training on vocational achievement. They turn, for this reason—and perhaps also because of their preconception, since it is not necessary to make any final interpretations—to the theory that, because the men less competent for business achievement are elminated in the earlier levels of the institutional organization, the men educated in college are more prevalent in business positions of the sort studied than those who were not so educated. And by the same sort of reasoning, it is said that

[26] *Cf.* Lott, *op. cit.*, p. 31, and Taussig, and Joslyn, *op. cit.*, pp. 166, 187–188 for such statements.

college men succeeded both in college and in business because of their general superiority and not because of what they learned in college.[27]

Such a view is certainly contrary to the interpretations of most educators, as well as to those of most students of eminent men. Nevertheless, something more than an assumption concerning the contribution made by education is required to support the correlations between eminence and education, and to refute the selectionist theory. If it can be shown that the individual gains something from the educational experience that he would not have gained otherwise and which is necessary for eminence, then the importance of education will no longer be in question. This is not easy to do, because of the interrelations of selective and contributive factors in every situation and for every person. Education in schools has not been necessary for the development of most of the greatest men of any historical period, if by greatest is meant the foremost ten of twenty. So far as we know every man who made great achievements and obtained great recognition, and who also had a formal education would have had essentially the same career if he had been associated with the same people during the same length of time and had obtained the same amount of prestige from the experience that was obtained by attendance at some college, university, or other school. The things that make education formal, in short, may have had nothing whatever to do with the result. But such statements as the above indicate some things of unquestionable importance that education does in a shorter length of time and more uniformly than can be done in other ways, and this may be true under favorable conditions for even the more able intellects. In the first place, formal education gives students opportunities for contacts with experts along certain lines, experts with whom the potential man of achievement might only with difficulty come into contact outside of the institution. Second, the period of time required to obtain the basic fundamentals of subjects is shortened by the organization of the curriculum, especially in places where there is flexibility for the benefit of the more able student. Third, it gives proportionately more leisure for study than can be obtained in any other way for large numbers of people. Fourth, it gives companions in study, opportunities for discussions, and the joint solution of difficulties. Fifth, entreé to the leading persons in certain fields is gained through colleges and universities either directly or indirectly through contact with lesser personages. And sixth, educational experience, especially in certain institutions and in certain grades or qualities of work within the institution adds to the individual's prestige in such a way that he makes faster progress toward recognition afterwards.[28]

It might also be thought at first glance that the direction of interests of persons of talent is a major contribution of the school. This does apply to lesser individuals, but many of the most illustrious persons had such definite interests so early in childhood that the school cannot be given credit for their development. The personages, of which this statement is most true are scientific, philosophical, musical, artistic, and literary notables, although eminent men tend to choose

[27] Taussig, and Joslyn, *op. cit.*, pp. 187–188. The theory of selection in education is old, and has been advanced by many sociological thinkers. See P. A. Sorokin, "Contemporary Sociological Theories," New York, 1928, Chapter V, and "Social Mobility," New York, 1927, p. 187 ff.

[28] *Cf.* Sorokin, "Social Mobility," pp. 169–172 for a discussion of education as a channel by means of which one rises to prominence. Prestige is one of the main factors defining the usefulness of a channel.

their careers earlier than the average person.

A glance again at the list of positive advantages of formal education makes it clear that there are conditions under which these gains are immaterial in comparison with the favorable circumstances of extremely fortunate individuals. The son of a foremost philosopher or scientist in an age of a low degree of specialization, or the son of a wealthy and brilliant father with a fine private library offer examples. Contact with experts, prestige from personal contacts, leisure, period of time required to learn the fundamentals are all present in superior degrees. And the stimulation of a more mature mind and personality is not at all rare. This combination was fairly common among the eminent personages of history. However, such a fortunate situation was always rare and is now even more difficult to attain, mainly because of the tremendous advances in all fields of knowledge, the great amount of specialization required for achievement in most fields of activity, and the phenomenal increase in the published materials that are beyond the scope of private libraries. Self-education is still possible in extreme instances, and education within the family is still possible as a first step to achievement along many lines, but with the advancement of specialization such opportunities are found to decrease, until it is possible that even the most favorable arrangement of circumstances outside of colleges and universities will fail to produce a great scientist and other types of leaders. Such at least appears to be the meaning of specialization in the fields of science and the technical advances in all of them away from interest in surface and common-sense aspects of the world.

The position that careful consideration forces us to take is thus that formal education is generally of importance in accounting for eminence. It is of more importance than the selectionists usually are willing to admit, but at the same time it is less important than the average educator will admit. Furthermore, the interrelations between the factor of formal education and the other factors in eminence are far more complex than is ordinarily believed. And finally, formal education's importance is dependent in part on the cultural situation and the sort of eminence under consideration. It is more important to-day in many fields than formerly and has not reached the limit of development. And it is always likely to be more important in fields of great specialization and removal from the level of activities of the ordinary world than in other phases of endeavor.

SPRINGTIME AND SALAMANDERS

By Dr. GAIRDNER MOMENT
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EVERY man, no doubt, has his own sign of spring's true arrival. Here in Baltimore it is apt to be the first hobo selling flowers in the street or perhaps the first crocus in the archbishop's garden. But for many biologists—and who should be more concerned with spring than they?—the advent of this loveliest of seasons is marked by an event almost no one ever sees. It is an event, none the less, which initiates weeks of feverish activity in many university laboratories and which is itself nearly as common as skunk cabbage and pussy willows.

This little understood phenomenon, so full of the mystery of spring, is the annual breeding migration of a salamander, the salamander which lays the eggs that are the modern equivalent of Louis Agassiz's famous turtle eggs.

Doubtless for the present day laboratory worker to witness the actual migration or the breeding behavior which follows is no more necessary than it would have been for Agassiz to have seen the turtle which laid the eggs Mr. Jenks, of Middleboro, collected for him so long ago. It would be much easier, however, for any one to observe the breeding of the salamanders than it was for Mr. Jenks to catch that turtle depositing her eggs. The salamander involved, *Amblystoma punctatum*, is one of the most abundant of the animals inhabiting the woods over a large part of the United States. Indeed, this migration which presents essentially the same problems involved in the migrations of birds or butterflies, can be studied close to most of our largest cities.

The reason so few people realize how common these animals are is that very few men, even very few naturalists, have ever seen an Amblystoma except on one night in the year. That night is the night on which they come down to the ponds, and very special ponds at that, to breed. At such a time you can see them in hundreds, sometimes in thousands, crawling and swimming over the usually leaf-covered bottom.

Amblystoma themselves are vigorous though just slightly awkward creatures about six inches long which greatly resemble plump and smooth-skinned lizards. Usually they are glistening ebony black with a row of bright yellow spots along each side and extending forward onto the blunt-nosed head. The effect is not unlike that of the lighted portholes of a ship. Exactly how these sturdy animals live during the remainder of the year is as yet largely unknown. Their obscure destinies probably lead them under the fallen logs and tangled débris which covers the floor of the woods adjacent to their chosen pond. Several, it is true, have been found during excavations far from any body of water. Certain it is that they shun the light, and it is entirely possible that they are nocturnal, emerging on dark and rainy nights to forage for earthworms and crickets or other small prey. This last, however, is speculation.

But there is no uncertainty about the fact of their annual migration nor does there seem to be any doubt in the minds of the salamanders themselves as to the date on which it is to take place. This is all the more remarkable because like Easter it is an elusive and movable feast. The best human prediction is about as reliable as your grandfather's almanac. "On the night of the first good rain after the first real thaw in spring." You are

not expected to ask how much rain is a "good rain" nor what constitutes a "real thaw." Only the Amblystoma know the answer to these or to any one of a dozen other puzzles which arise from erratic spring weather conditions. Perhaps, as has been determined for the oyster, there must have been a certain minimum temperature maintained for a certain minimum time before the breeding reactions will occur.

In general, by the night the salamanders start their migration the ice has melted from around the edges of the pond, although some remains in the center and in out-of-the-way corners. Often along the moist bank skunk cabbage has begun to force its way up through the dead leaves. At the same time the wood frog, the earliest frog to spawn, is just waking from its hibernating sleep and appearing in these same localities.

Considerable perseverance is apt to be required to see the migration. One night too early and you will see nothing. One night too late and the big show is over. The only way which never fails is to inspect the selected pond equipped with flashlight, boots and raincoat, every rainy night, the darker and rainier the better, beginning very early in the spring before there is any question of a "good thaw."

On the right night, if the thaw has been a real one and the rain good, you will see on the bottom which on all the previous nights was deserted save for a stray water mite or two, a writhing mass of spotted salamanders milling around in a frenzy of cold excitement. So numerous are they and so unconscious of all but one dominant impulse that you can reach down into the icy water and catch them without the aid of any net. On this first night they prove to be almost exclusively males. If you sweep the banks with your flashlight you will surprise other males, sometimes at a considerable distance from the water, but on their way down to the pond where they will join the throng of glistening black animals with bright yellow spots. The dance continues hour after hour.

The next morning the pond will again be deserted, so completely deserted that you are forced to wonder whether or not you really could have seen what you remember from the night before. Overturning half a dozen partially submerged logs or rocks will reveal no confirming evidence in the form of salamanders. But out on the floor of the pond where the excitement was at its greatest are multitudes of what appear to be little pinches of white cotton attached to submerged leaves and sticks. These little flecks of white, not quite the size of your little finger nail, are the spermatophores, packets of sperm which the males have left behind them and which are now waiting for the females.

Picked up and examined, they appear to be composed of a whitish jelly-like material which when torn apart will release the spermatozoa. Under the lens of a compound microscope each sperm is a creature of amazing and delicate beauty. The head is the shape of an exquisitely fine and slightly curved needle. From it extends a long slender thread, the tail. Along the side of this tenuous and slowing waving tail runs an undulating membrane so delicate that it is visible only when the light of the microscope is adjusted with the utmost nicety. Then it reveals itself by its rapid and never ceasing series of undulations arising at the head and increasing in amplitude as they pass back towards the end of the tail. It is by means of this tail that the sperm swims.

If the rain continues and the next night is dark, females, driven also by some unknown force, will appear in the pond. Sometimes of course it will clear and the pond freeze tight, thus delaying the females a week or even longer. But the

sperm packets remain and when the females do arrive something leads them to seek out the spermatophores which the males have left and insert them into their reproductive tracts. It amounts to artificial insemination, a feat which man has only recently achieved. Presumably there is some secretion, possibly some enzyme, in the female's cloaca which dissolves the jelly and releases the sperm. In any case, even though the female Amblystoma usually never sees the male, the actual fertilization of the eggs takes place within her body. Of course there are many salamanders like the common greenish yellow pond newt which do have an elaborate and even rather rough courtship. But this is not the case with Amblystoma. The sperm-packet depositing ceremony is a strictly stag affair. For several days after the original male migration a few individuals of both sexes can often be found in the same pond on the same night and on one occasion I saw a pair pass each other on the bank, the male going away from the water, the female toward it. Yet under all these circumstances they remain completely indifferent to each other.

Of the actual nature of the instincts and tropisms which bring about this migration and breeding reaction we at present know almost nothing. It is very difficult to tell without knowing from actual observation which ponds will be visited by Amblystoma and which will not. It's easy enough to locate ponds they ought to lay in but don't. One of their favorite sites is an old bend of a stream which has been cut off from the main channel so that it no longer has any appreciable current. Nothing, in fact, pleases them more than what geologists call "ox-bows," although their choice is by no means limited to such situations. So far as I have observed the only generalization possible is that a pond where Amblystoma lays is always in or near a woods, although the woods may be very small, in fact surrounded by built-up city streets.

It is not unlikely that the adults always migrate *down* to the ponds in spring. The animals I have seen entering the water have always been coming down from a hillside. But this is only a guess. Certainly if they wander very far during the summer, merely marching straight down hill when they first become active in the spring must often bring them out far from any pond. And even supposing it is true that all Amblystoma on first awakening in the spring walk down hill, this astonishing fact is itself quite unexplained. Once in the proper pond, it would seem probable that the females swim about until they are attracted by some odor given off by the spermatophores. This odor is also probably the stimulus for the females to place the sperm packets up their reproductive tracts.

The eggs themselves are subsequently laid at intervals during a period of ten days to two weeks. They are usually mistaken for a frog's egg, although each one is slightly larger than a frog's egg and of a soft cinnamon brown. The jelly in which each cluster is embedded is considerably stiffer than is the case with frogs and is as clear as the clearest Copenhagen glass.

It is not, however, their beauty but their usefulness and availability which has attracted biologists. Ever since Agassiz made his classic study on turtle eggs (and in fact before) the problem of development, of how a complicated animal arises from a simple egg has been one of the central problems of biology. To-day, in the work of an entire school of biologists, the problem of the origin of the individual occupies the same position that the question of the origin of species once held. Indeed the first problem now seems to be the key to the second and to many other problems.

However that may be, almost all the

modern theories of development have been worked out on the eggs of salamanders because they lack the fetal membranes which surround the embryos of all higher animals, even turtles, and make experimentation extremely difficult. It was for his work on the egg of a salamander that Spemann received a Nobel prize.

So every spring in this country and in many others thousands of salamander eggs are taken into laboratories to be used in a far greater diversity of experiments than Agassiz could ever have imagined. But long before these are concluded, the Amblystoma will have disappeared and the ponds will remain deserted until after a full roll of the seasons, when there will be another good rain and sufficient thaw.

WHY THE SOCIAL SCIENCES LAG BEHIND THE PHYSICAL AND BIOLOGICAL SCIENCES

By JOSEPH MAYER

HONORARY CONSULTANT IN SOCIOLOGY, LIBRARY OF CONGRESS

We often hear the question raised these days as to why the social sciences continue so backward, while at the same time the physical and biological sciences have moved forward with unprecedented rapidity in the past 100 or 150 years.

Attention is constantly being drawn to the marvelous advances of physics and chemistry that have resulted in the invention of the steamship, railroad and ocean cable, in the application of electrical energy to many practical uses, in the development of gasoline combustion and in the synthetic products growing out of applications of chemical discovery. In geology and biology, also, rapid strides have been made in the past century. But over against these advances there apparently has been little, if any, real progress in an understanding of human relations and in the solution of problems such as war, minority protection, unemployment, maldistribution of wealth and income or depression.

In endeavoring to clarify the reasons for this sharp contrast between rapid progress in one direction and sluggish progress in the other, one may profitably trace the history of science from early Greek times to the present day. A definite sequence of development is indicated, from the most abstract understanding of nature to the more concrete problems which we designate as human or social. Mathematics seems to have been the only science that the ancient Greeks succeeded in establishing on a fairly secure basis, even though certain mathematical developments were left to the later Hindus, as in the so-called Arabic notation and the symbol zero, which developed centuries afterwards. The ancient Greeks attempted to understand other branches of knowledge in addition to mathematics. They assembled considerable materials in the fields of astronomy, physics, geology and biology. But knowledge at the time was so meager in these fields that in most of them the Greeks handed down to their successors about as much misconception as accurate information. Aristotle, the greatest of the ancient Greeks, held back progress, through the misconceptions he fathered, about as much as he cleared the way for further advance in the development of such rigorous techniques as logic and the inductive approach to an understanding of nature.

It was not until after 1600 A. D. that the next important steps in scientific development occurred. Around 1600,

astronomy shook off the misconceptions that had prevented its constructive advance and, with the work of Kepler and Galileo, established the Copernican system which to-day forms its secure basis. Had it not been, however, for some of the mathematical developments of the ancient Greeks, especially those having to do with conic sections, Kepler would not have been able to discover the laws of planetary motion. It should also be noted that the great work of Galileo in astronomy depended to some extent upon the development of the telescope, a product of physics.

Physics and astronomy are, to be sure, very closely related in their fundamental principles. Soon after astronomy was established as a science, Sir Isaac Newton laid the foundations for further advances in mathematics and astronomy and especially in physics. In these developments he was aided considerably by additional important work by Galileo and other scientists. By 1700, physics was well along the road to a discarding of past misconceptions and to a building of that foundation which has made possible the important practical advances of the past two centuries.

Another century passed before chemistry, aided by the development of certain principles in physics found a secure basis for its own establishment as a science, at the hands of such men as Black, Priestley, Cavendish and Lavoisier. By the time of the French and American Revolutions, this branch of knowledge was also on its way to a constructive development. By the third of the next century, enough groundwork had been laid for the extraordinary advances in organic and then in inorganic chemistry that followed.

Until physics and chemistry were well enough along in the development of principles and of such tools as the microscope, the balance and the thermometer, it was impossible for geology and biology to find sufficient root for their modern advance. It was not until 1830 that gross misconceptions regarding geological phenomena were being swept away and that Sir Charles Lyell, in his writings, was laying the foundations for modern geology. And it was not until 1860, or thereabouts, that the three great generalizations were developed which laid securely the foundations of modern biology. These were the discovery of the cell and protoplasm, the discovery of the germ layers and the enunciation of the evolutionary hypothesis. From 1860 onward, we find the gross misconceptions of biology disappearing, and scientific hypotheses regarding life processes, upon which a reliable structure could be erected, taking their place.

It was hardly possible to understand anything clearly about psychology or the things of the mind until that part of biology was far enough advanced which deals with the structure of the sense organs, such as the eye and the ear, with the tracing of the nervous system, and especially with the analysis of the functions of the spinal cord and the brain. These developments did not come until the last half of the nineteenth century. It is not strange, therefore, that modern psychology takes its beginnings from such men as Wundt in Germany, who developed physiological psychology, from Charcot, Janet and Freud in France and elsewhere, who developed the meaning of the subconscious and the important devices of hypnosis and dream analysis, and from William James in the United States, who, toward the end of the century, brought together the various fragments of psychological advance and laid the foundations for modern psychology.

For an understanding of social relations, whether political, economic or more general, it is necessary, first, to have a sound understanding of the environment

in which the human being finds himself, which is the task of most of the sciences we have outlined, and, second, of man himself, that is, of his biological and psychological limitations and potentialities. Such an understanding was impossible until biology and psychology were far enough along the road of modern scientific development. It is only now, in fact, that any satisfactory understanding of social phenomena is becoming possible. Thus it is not peculiar that the social sciences should have lagged behind the physical and the biological sciences, awaiting the day—which is our own day—when sufficient background might be available for constructive advance. There still exists in the social disciplines any number of misconceptions, carried down to us from the past and particularly from the medieval period, which must be swept away before we can make rapid progress in the social studies. With respect to these further tasks, it might be added, I have attempted a somewhat detailed analysis of a ground-clearing nature, in two recent articles, appearing in the July and October issues, 1936, of the journal, *Philosophy of Science*.

We may not even now be ready for this rapid advance in the social studies; but, at any rate, in the light of the history of science, we can at least understand why it is that there is so much uncertainty, hesitation and misunderstanding in contemporary efforts to solve social problems. Only as we reach down into all the sciences that are antecedent and utilize them for the task ahead, can we hope some day to have as clear an understanding in economics and government and sociology as we have long since secured in the physical and in the biological sciences.

TANTALUM CARBIDE:

A SUBSTANCE WITH THE HIGHEST KNOWN MELTING POINT

By PHILIP M. McKENNA

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WHY should a substance with the highest known melting point be of interest to the natural philosopher? First, because extremes are always interesting as testing generalizations drawn from limited ranges and extrapolated to conditions not yet tested. Second, because the various properties of substances are correlated, and the possession of one extreme property may imply other interesting attributes. Third, because our control over experimental conditions is aided in a practical way when we find a new tool or substance with which we may work.

Tantalum carbide has a melting point of 4150° absolute or 3877° C, plus or minus 140°. (It is true that hafnium carbide is reported to have a melting point 10° higher than this, but the scarcity of hafnium and its difficulty of separation from zirconium leaves the immediate domain of highest melting point to tantalum carbide.)

Tantalum carbide has been prepared in crystalline form having metallic golden luster. So prepared, it had a higher density than hitherto reported, namely, 14.48, while previous compounds of tantalum and carbon were reported as only 13.95 to 14.05 density. Strange to say, this new tantalum carbide has a slightly higher carbon content than previously reported for the combination of tantalum and carbon, namely, 6.224 instead of 6.20. This was a surprise, as carbon is a very light element compared

to tantalum. Evidently the carbon in this new form of TaC is packed more closely or in more orderly arrangement.

By x-ray crystallographic analysis it was determined that the crystalline form was similar to that of common salt, NaCl, with alternate atoms of Ta and C in cubic face centered arrangement. A pleasant confirmation of the lattice dimensions, atomic weights and density was obtained by back reflection precision x-ray diffraction methods, for the distance between the Ta atoms was deduced from these x-ray photograms to be 4.445 Ångstrom units. Calculating what the density should be if the unit cube contained four molecules of TaC and unit atom weight 1.6489×10^{-24} grams, the following results are obtained:

$$\frac{4 \times 192.88 \times 1.6489 \times 10^{-24}}{(4.445 \times 10^{-8})^3} = 14.47$$

This was very close to the observed density of 14.48.

Why should TaC have this high melting point, higher than either carbon or tantalum alone? Because it is a compound, rather than a solid solution or eutectic, seems a good answer. Carbon boils at about 3600° C, and tantalum melts at 2850° C, but the compound TaC melts at 3877° C +/− 140°. That the melting point of tantalum carbide is really higher than the vaporization point of carbon has been shown in an interesting experiment reported by Agte and Alterthum.[1] In this experiment tubes of tantalum carbide were fastened between water-cooled electrodes in a sealed glass vessel filled with hydrogen or in other cases with argon-nitrogen mixtures. Inside the tube carbon blocks were placed. By conducting low voltage heavy ampere current through the tantalum carbide tubes they attained high temperatures and the carbon blocks began to vaporize at 3450° C and sublimed onto portions of the glass vessel. Temperatures of 3630° to 3827° C were maintained without destruction of the tubes and with vaporization of the carbon.

[1] *Zeitschrift für technische Physik*, No. 6, pp. 188 and 189, 1930.

Another carbide of a refractory metal, namely, tungsten carbide, has a melting point lower than either the metal tungsten or carbon. Tungsten metal melts at 3370° C, while the carbide WC melts at 2867° C. In this case we have the so-called compound with a melting point lower than either element. In general, the carbides of elements Ti, Zr, Hf, V, Cb and Ta, which are in the fourth and fifth groups of the periodic table, have higher melting points than the metal alone, while carbides of elements of the sixth group, such as chromium, tungsten and molybdenum, have melting points lower than the metal. It may be significant that tantalum carbide has a positive heat of formation, while tungsten and carbon apparently have approximately zero heat of formation.

Columbium carbide also has a very high MP, namely, about 3500° C.

Table I, compiled after Ernst Friederich, is an effort to correlate physical properties with the valence and distance of atoms apart, assuming that forces exist varying inversely as the square of the valence.

It will be observed that the hardnesses and melting points ascend with an increase in the factor

$$\frac{100 \times W^2}{V_a^{2/3}}$$

The exception seems to be vanadium carbide; experience with it seems to show that it breaks up into V_4C_3 and that the compound VC does not persist up to the melting point. This series consists only of compounds having the NaCl type crystalline lattice. While this factor is apparently only an approximate measure of the properties of substances it shows tantalum carbide at the high end of the series, as is its rank in melting point and hardness as far as may be determined.

The mechanics of "hardness' needs definition and clarification. Breakage of

TABLE I

FIGURES OBTAINED BY CONSIDERING THE VALENCE SQUARED DIVIDED BY THE ATOMIC VOLUME TO THE TWO-THIRDS POWER IN A SERIES OF COMPOUNDS SODIUM CHLORIDE TYPE CRYSTALLINE ARRANGEMENT

Compounds	NaCl	AgCl	NaF	PbS	CaO	MgO	TiN	ScN	VN	CbN	TiC	ZrC	HfC	VC	CbC	TaC
Valence	1	1	1	2	2	2	3	3	3	3	4	4	4	4	4	4
Density	2.2	5.56	2.83	7.42	3.37	3.65	5.18	4.46	5.63	8.40	4.25	6.90	12.20	5.36	7.82	14.47
Lattice[a]	5.628	5.54	4.62	5.97	4.79	4.20	4.40	4.44	4.28	4.41	4.60	4.76	....	4.30	4.46	4.445
Atomic vol.	13.53	12.8	7.42	16.1	8.39	5.57	6.17	6.65	5.77	6.42	7.05	7.48	7.81	5.87	6.708	6.67
$100 \times \frac{W^2}{V_A^{2/3}}$*	18	19	26	63	97	127	268	255	280	260	435	418	406	491	450	452

[a] These compounds are all of the same crystalline form—NaCl type cubic. The distance a is the number of Angström units between similar kinds of of atoms.
* W = valence; V_A = atomic volume = atomic weight/density.

crystals probably occurs at the larger fissures attributed to the mosaic structure, rather than between atoms in a lattice. Crystalline form also governs the way substances break under strain, for if slippage may occur without breakage we have malleability. A more comprehensive knowledge of "hardness" may be increased by a study of this extreme member of the series of substances, tantalum carbide.

How tantalum carbide is already serving as a new tool for man's control over his environment is exemplified in the use of tool materials utilizing its properties of resistance to deformation and wear. At present its greatest use is in a series of hard tool compositions containing from 17 to 80 per cent. of tantalum carbide, together with tungsten and other metals such as nickel and cobalt. Pieces of these hard metal compositions are used as tool points, for lathe tools, boring tools, reamers and drills for cutting metals, particularly hard steels. The use of tantalum carbide has greatly extended the possibilities of engineers in constructing machine parts of harder steels. With steel tools, including those alloys of tungsten and chromium used for tools, the machinable range was regarded as below 300 Brinell. Now steel axle shafts and other articles are machined with ease at hardnesses up to 555 Brinell, providing an increase in tensile strength from 148,000 lbs. per sq. in. to 271,000 lbs. per sq. in. in the finished parts.

Other interesting uses are based upon the resistance of tantalum carbide to corrosion. Nozzles and valves operating under acid conditions are now used in various appliances. Tantalum carbide may be boiled in all acids except a mixture of hydrofluoric and nitric without oxidation or attack.

As the world becomes aware of the properties of high melting point carbides they will be found to extend our control over our environment just as the discovery of the use of iron for tools marked a cultural step from the stone and bronze ages. To the experimentalist, endeavoring to utilize conditions of temperature and pressure to investigate changes in matter, tantalum carbide may provide apparatus which is needed.

Thus we may justify an interest in this unique compound to the scientist, as exemplifying an extreme of a series; to the engineer, as providing a new tool; and to the experimentalist as a new thing to achieve his purposes.

COMMENTS ON CURRENT SCIENCE

By SCIENCE SERVICE[1]
WASHINGTON, D. C.

THE WASHINGTON FIELD MUSEUM

Unique among museums in the United States is one in Wash ngton, N. C., which has been developed and is operated in regular, full-scale museum style by the young folks of the town, mostly those of high school age. The Washington Field Museum, as it is called, is a full-fledged member of the American Association of Museums, and its youthful curators spent part of their spring vacation time in visits to its larger sister establishments to learn some new tricks of the craft for their own use.

It all started back in 1923, when a few high school students pooled their amateur collections of butterflies, snakes, etc., in a tent made of sacking. They named their embryo institution "The Bughouse Laboratory."

Instead of dying out presently, as such ventures are apt to do, the Bughouse Laboratory survived. It moved into a backyard kitchen, then into an empty store building. The Bughouse Laboratory became socially "the thing"; membership on its staff was more desirable than a bid to a fraternity.

Successive school generations graduated and grew up, and their younger brothers and sisters took their places. The "founding fathers," still young folks, began to have influence in the community. They secured a plot of land, which has been developed into a neat little park. A lumber company donated building materials, WPA labor was secured, and presently the Bughouse Laboratory moved into its new quarters, and added to its title the more formal style of Washington Field Museum.

[1] Watson Davis, director, Frank Thone, Robert D. Potter, Jane Stafford, Emily C. Davis and Marjorie Van de Water, staff writers.

There is a full-time director, Miss Mary Shelburne, but the rest of the curators are still boys and girls from school. They pursue all branches of research and collecting, with special emphasis on natural history and early Americana. A number of live animals have been donated, so the museum is now in the process of developing a zoo.

TESTING FOR SURFACE ACCURACY

A human hair about 15 feet across. That is what it would be if it were magnified with one of the latest testing devices for automobile parts.

One of the wonders of modern mechanical engineering is the routine measurement of finely finished surfaces so smooth that magnification of the order of 50,000 times is necessary. So exacting have become the demands of modern machine shop practice that the working surfaces of anti-friction bearings, for instance, require great accuracy and smoothness. Surface irregularities less than a hundred thousandth of an inch (10 microinches) are cause for rejection.

A machine that measures so finely with the rapidity necessary in actual production, has been achieved. The profilometer, as it is called, has a tiny point that traces the almost molecular surface irregularities. This varies the current flowing through a magnet and this current is sent through special amplifiers and circuits. Thus, electrically, there is created that high magnification necessary. The magnified replica of the surface desired is the light-written record of the oscillograph into which the current is fed. If a permanent record is desired, a motion picture camera is aimed at the waving light line of the oscillograph.

How far machine shop precision has traveled during the age of power will be realized when it is recalled that Watt, inventor of the steam engine, was elated when he found that Wilkinson's boring mill could machine an engine cylinder true to within the thickness of a shilling. The dawn of precision in machinery came when the system of interchangeable parts was adopted early in the last century. Arms factories in Connecticut pioneered in measuring accurately with gages. With accuracy increased many fold, this in the principle that underlies the machine age of to-day.

PIPED RADIO CIRCUITS

The enormous carrying capacity of the new "piped radio" systems, developed independently at Massachusetts Institute of Technology and the Bell Telephone Laboratory, is still little realized. In this system, it will be recalled, radio waves are sent down pipes, around bends, and so on to their destination.

A hollow pipe two inches in diameter, for example, can transmit a band of radio frequencies amounting to a width of ten billion cycles a second. This sounds complicated but can be better appreciated if one says that it would permit 2,000,000 people to talk with each other (two to a conversation) over the same electrical circuit. This is allowing frequency channels of a band width of 10,000 cycles a second; quite sufficient for ordinary conversation. Citing the work of Dr. Wilmer L. Barrow, of the Massachusetts Institute of Technology, the *Technology Review* contrasts the message-carrying capacity of wires and cables.

An open-wire telegraph line has a band width of 100 cycles per second and permits one message to pass. An open-wire telephone line has a band width of 3,000 cycles and has one message channel. Open-wire carrier telephone lines have a band width of 30,000 cycles and allow four simultaneous messages. An improved circuit plans for 16 messages.

The coaxial cable would permit 120 voice messages or one television message. Television radio bands have a band width of well over 5,000,000 cycles and carry one television message. The "piped" radio method has a band width of 10,000,000,000 cycles. It could carry 1,000,000 telephone conversations or 2,000 television messages over the same circuit. Dr. Barrow has found that the "pipe" need not be continuous and that the radio waves will jump gaps up to one inch in length.

THE STUDY OF HUMAN BONES

Because human bones are made up of mineral salts, medical scientists have borrowed some of the geologist's methods in order to learn more about bone structure. The geologist turns powerful x-rays onto minerals and by a process known as x-ray diffraction, he can see the pattern of the molecules in crystals of a given mineral. Dr. W. D. Armstrong, of the University of Minnesota, has used this same method to determine the pattern of molecules in crystals of calcium, phosphorus and other mineral salts in human bone.

His findings, reported at a recent meeting of physiologists, led to the same conclusions as those of Dr. M. A. Logan, of Harvard University, who studied bones by a chemical method. Dr. Logan started with calcium phosphate and by chemical processes, adding a molecule here, taking off a molecule there and otherwise manipulating the original material, he traced the chemical life process of bone salt. In the end he found a chemical pattern for the arrangement of molecules in bone salt crystals that was the same as that found in Dr. Armstrong's x-ray diffraction patterns.

Using physiological methods for studying the problem, Dr. F. C. McLean, of the University of Chicago, discovered

a means of calcium transportation and mobilization for bone formation. Under the influence of the hormone produced by the four wheat-grain-sized parathyroid glands in the neck, calcium is transported from bone to blood via the bone marrow, where some of the new blood cells are formed.

Bone salts, contrary to general opinion, are not stable and permanent, Dr. J. C. Aub, of Harvard, found. They are constantly being dissolved and shifted to another part of the bone, where they are redeposited as crystals, and then redissolved and moved again. This new knowledge was gained from studies of patients poisoned years ago by radium.

COAL, WATER AND AIR A SOURCE OF MEAT SUPPLY

Germany already enduring economic siege conditions, and apprehensive of the sterner blockade of war, looks increasingly to her chemists to make her internally self-sufficient. Newest among projects that would smack of magic if they were not based on well-determined scientific principles is one to make coal, water and air the ultimate sources of a meat supply.

The key to this biochemical paradox is the yeast cell. Yeast produced in great masses and fed on cheap carbon-containing foods, plus nitrogen-containing mineral salts, will yield about half its dry weight in crude protein, the stuff lean meat is made of. This yeast protein is not suitable for direct human consumption, but it can be fed to livestock and thus transformed into meat and milk.

During the World War, yeast was raised in considerable quantities, on beet-sugar molasses, waste liquor from starch factories and similar low-grade carbohydrate sources. The nitrogen part of their diet was synthesized out of the air.

After the armistice, mass production of yeast feed became unprofitable, due to the competition of imported meat and cattle feeds. However, experiments have continued, with the objective of making yeast production cheaper. Promising materials have been surplus potatoes and sugar made from wood.

Now, according to Dr. K. R. Dietrich, chemist of Berlin-Dahlem, strains of yeast have been isolated that do not need sugar but can thrive perfectly well on such carbon-containing compounds as lactic acid, acetic acid, glycerin and even ethyl alcohol, plus of course the usual ration of nitrogen captured from the air.

But some of these compounds can now be produced from coal and lignite, by new synthetic processes. Hence the prospect that some day German steers may be making beefsteak out of coal, air and water, via the humble yeast cell.

THE SURGEON'S CHIEF JOBS

In these days when so much is heard about gall bladder operations, surgical cures of cancer, gland grafting and plastic surgery, it is interesting to find that setting broken bones, one of the earliest jobs tackled by surgeons, is still one of their most important, numerically speaking.

Setting of fractured bones stands second in order of frequency, coming right after removal of tonsils, it appears from a statistical study by Selwyn D. Collins of the U. S. Public Health Service's National Institute of Health. A report of the study was recently published by the Milbank Memorial Fund. Mr. Collins obtained his figures from a canvass of 8,758 white families living in 130 localities in 18 states of the union. The canvass was conducted between the years 1928 and 1931 and covered 12 consecutive months.

For every 1,000 persons in this group, 65 surgical operations were performed in a single year. This means the total number of operations in this country each year totals close to 1,000,000. Of these, removal of tonsils constitutes

nearly one third. Setting of broken bones and other operations in connection with injuries take second place and third place respectively and together account for one fifth of all operations. Operations on female organs of reproduction are fourth in order of frequency and removal of the appendix came fifth.

Slightly more operations are performed on women than men. Setting broken bones and other operations in connection with injury, hernia and sinus operations are more frequent in men. Appendectomy, gallbladder, cancer and thyroid operations are more frequent in women. As might perhaps be expected, the frequency of operations increases with income. There is some difference, too, in types of operations according to income. You have to be up in the higher brackets, it appears, before removal of tumors and ear and mastoid operations are undertaken frequently.

A SIXTEENTH CENTURY REPORT OF ASTHMA

The idea that a man can get asthma from sleeping on a feather pillow is still a new idea to many laymen. Actually, a case of asthma was attributed to feathers and cured by removing the feather bed as long ago as 1575. In that year Jerome Cardan, a great physician of Padua, was called to Edinburgh to see the Archbishop who suffered from asthma. The Paduan physician probably had no idea of allergy, or hypersensitiveness to feathers, such as physicians have to-day. Certainly he was not able to make skin tests of his distinguished patient. But Cardan was able, as good physicians have always been, to observe and study his patient carefully and to make logical deductions from his observations. Cardan finally advised the Archbishop to give up certain articles of his diet and to get rid of his feather bed. Relief of the asthma promptly followed.

The story is retold by Louise Stedman and Merle Ford in a report to the *Journal of Home Economics*. The report concerns itself with textiles which, like feathers, plant pollens and foods, can cause asthma, hay fever, migraine headaches, hives or other forms of allergy.

Cotton, silk, wool, kapok, rayon, leather and rubber can all cause allergic symptoms in hypersensitive persons, but of the fabrics silk seems to cause most trouble. Cottonseed and flaxseed or linseed are troublesome in cases where cotton or linen fabrics may not be. Kapok may not cause symptoms at first but when the fibers become dry and brittle they cause a fine dust which may be troublesome. Dyes used in fabrics are often allergy-causing in themselves. Rayon waste is said to be one of the safest nonallergic upholstery stuffing materials. Smooth fabrics can often be tolerated when a rough weave of the same material causes trouble.

SOIL EROSION

Malthus' ghost has returned to haunt us, in a new guise.

During the nineteenth century, the principles of Malthus, first set forth in his famous essay on population in 1798, were among the dominant ideas in political and social thinking. Briefly, Malthus took the gloomy view that human population always tended to increase faster than its food supply, and that misery and want and war were the inevitable consequences.

Malthus left out of consideration (for the good reason that he did not know anything about them) a number of factors that have operated at least in part to prevent realization of his pessimistic prophecy. Improvement of crop plants and food animals, invention of more efficient cultivation methods, and better means of keeping and marketing food have done much to increase the food supply. Later marriage, wider use of con-

traception and possibly other factors have slowed down population increase.

But just as we are congratulating ourselves on the laying of the Malthusian ghost, up it pops again, out of the gullies of eroded and abandoned farm lands. Professor Paul Sears, author of "Deserts on the March," expresses it as a general principle: "In the development of any civilization, the total area of cultivable land tends constantly to diminish."

Professor Sears has pointed out the working of this principle in all the world's dead and dying cultures: Syria and Chaldea, Rome and China—and our own. Not only for necessary bread but for swollen profits, men strip the forest, pasture goats on the hills, tear the banquet-cloth from earth's table with overeager plows. Ruin has always followed. Ruin threatens now.

Yet there is time. Just as we eased the pressure of the older Malthusianism with better crops better cultivated, so now we can restore forests and grasslands, stop gullies, plow more sensibly. It will cost money, require more effort. But the alternative choice is decline and ultimate death.

A STUDY OF SLIPPERY ROADS

Using some of the fingerprint tricks of Scotland Yard, the Department of Scientific and Industrial Research of Great Britain is now studying slippery roads by taking fingerprints of motor car tires.

As reported in *Industrial and Engineering Chemistry,* published by the American Chemical Society in Washington, D. C., the road under study is coated with an ink and a perfectly smooth tire rolled over it. The tire is then transferred to white paper and an exact record of the texture of road surface, over which the tire has rolled, is obtained.

Slippery roads have been found to be those in which there is a high ratio between the total area of contact between tire and road and the number of isolated points of contact. The latter, isolated areas, must be surrounded by channels deep enough so that the water on the road can escape as the tire passes over. If the channels are too small the individual areas merge and the surface behaves like a smooth one. The requirements for non-skid tires are similar. On very slippery roads studies show that the tire makes contact with the pavement over nearly all its surface of contact while the number of individual contacts is small. Good roads, low in skid values, were found to be those yielding prints that disclosed a lesser area of total contact and many more individual points of contact. A "sandpaper" surfaced road, with its many tiny and almost imperceptible points of irregularity, is typical of a highway low in slipping characteristics. Not only are different road surfaces being studied, but tests are also underway to study the skidding characteristics of the same roads at different times of the year.

EXTERMINATION OF THE WHITE-FRINGED BEETLE

War's grimmest machinery—flamethrowers, poisonous chemicals, even the "scorched earth" tactics made famous in the Chinese conflict—will be brought into concentrated operation in the South this spring, and all against an enemy only half an inch long. Major fighting will begin late in June, when the white-fringed beetle, an invader from South America, emerges from its underground winter quarters.

The white-fringed beetle appeared in the United States for the first time only last summer, and its distribution is still limited to about ten scattered small areas near the Gulf of Mexico, from the western end of the Florida panhandle to a point near New Orleans. It is the hope of federal and state entomologists that

they can wipe it out entirely by drastic measures, as they did the Mediterranean fruit fly in Florida a decade ago.

At present the insects are safe from human attack. They are still grubs, feeding on the roots of plants. But in early summer they will appear above ground, to migrate, mate, and lay eggs. Then is the time for attack. Where the beetles are thickest, the earth will be swept clean of all vegetation, sprayed with oil not only to kill the insects but to keep plants from growing. With no green stuff to eat, the beetles will starve and of course produce no offspring. These thickly infested spots will also be circumvallated with trenches to blockade the enemy within, and flame throwers will move back and forth, spreading fiery death.

Where there are fewer of the beetles, crops may be grown; farmers are advised to plant corn, which the beetles do not like, rather than such southern crops as sweet potatoes and velvet beans, which they find more appetizing. Cotton is also recommended, for the beetles will gather on the leaves, where they can be reached with sprays or dustings of calcium arsenate which has been found effectively lethal to this pest.

PLANT SOCIOLOGY

Diverse social groups that just don't get along with each other often base their mutual dislike on things scarcely tangible yet very potent, like alien modes of speech or unaccustomed cooking odors. Dinty Moore's redolent kettle of corned beef and cabbage is more than a comic-section joke; it is the boundary marker between hostile cultural states.

Plants no less than human beings often develop feuds or friendships from much the same sort of subtle chemical causes. Dr. Gerhard Madaus, a German physician, has made a special study of some phases of this "chemical plant sociology," which started with his experimental plantings of drug plants but has been extended to take in the likes and dislikes of several varieties of crop plants as well.

Dr. Madaus calls attention first to the often-observed fact that the plant growth in certain types of evergreen forest is sparse, and poor in number of species. Most plants can not tolerate the acid compounds from the trees' needles. He also cites experiments by American as well as German plant physiologists, wherein the mere presence of odorous plant substances, such as the scent of apples, oil of bergamot, or turpentine, accelerate seedling growth in light but hinder it in darkness.

Of greater economic significance, possibly, are his experiments with paired species grown together and separately. Thus, he found that corn and wheat planted in the same pot produced a more rapid growth of wheat. Bean seeds in water that had bathed the roots of oats sprouted more quickly than did similar seeds in water from corn roots. Grapevines with cypress spurge (a common vineyard weed) growing close to their roots failed to set fruit. In some instances it is known that root secretions are responsible for these mutual effects, and it seems quite likely that similar substances act in like manner in other cases.

RUBBER CONTENT OF DESERT MILKWEED

Edison's experiments with goldenrod as a possible source for rubber were a nine-weeks'-wonder in their time. But Edison died, and his successors have apparently done nothing further with goldenrod rubber. At any rate, they have said nothing about it.

Less conspicuous but more persistent has been the work of botanists of the U. S. Department of Agriculture. Always before them is the hope of finding within the boundaries of the United

States some source of rubber that can be worked if a world war or other emergency cuts off the normal supply from across the Pacific.

R. E. Beckett, R. S. Stitt, and E. N. Duncan have recently reported analyses of a species of desert milkweed that show its leaves to contain as high as 13 per cent. of rubber, dry weight basis. They have grown the plant from seeds at the U. S. Acclimatization Garden near Bard, Calif., and find that strains of the weed with hereditary tendency to high rubber content can be isolated.

The three botanists describe the milkweed as growing in solid clumps of ten or twenty stalks, from three or four feet to six feet high. It is native only in the drier parts of the Southwest and adjacent parts of Mexico. They found it growing only in gravelly stream beds that are dry most of the time, and in borrow-pits along roadsides.

Harvesting the milkweed, even for experimental purposes, had to be done during a comparatively limited time, because it has the habit, common among desert plants, of losing its leaves soon after maturity. However, the dried plants could be stored for many months without noticeable loss of rubber content.

If it should ever become economically desirable or necessary to cultivate the plant, milkweed farms should not be difficult to establish, for seeds are abundantly produced and germinate readily.

DECLINE OF THE WHALING INDUSTRY

The sad state of a once-glorious maritime industry—whaling—is typified by the number of vessels in the whaling fleet accredited to the United States. Back in 1846 America had 735 vessels at sea catching whales, says Commissioner Frank T. Bell, U. S. Bureau of Fisheries. To-day the nation has—well take a guess for yourself before you read the next line.

The answer is three factory ships and 31 small killer boats! Two shore stations also still exist.

In 1846 whaling employed 40,000 people of American nationality, had an investment of $40,000,000 in its ships and other equipment and made an annual catch valued at $8,000,000. To-day America's small whaling fleet produces products having a value about a third as great as in 1846, or approximately $2,600,000. The return on the investment is about as good as it was back in the peak period of American whaling.

Whaling, which now interests the world more as a conservation effort than as a leading industry, has gone through three distinct periods, says Mr. Bell. From the time the first Basques started whaling in the 12th century until 1868, harpoons were thrown by hand in a sort of personal hand-to-hand combat with the giant sea-going mammals. In 1868 the invention of the harpoon gun speeded the kill and enabled greater efficiency in hauling the whales to the shore processing stations. The third, or modern, era has been the establishment of factory ships which process the whales at sea, far from their home ports or shore stations.

One whale yields as much meat as 100 cattle and in Japan is sold for food, to people too poor to buy beef. A contrast between the old and new in whaling is typified by modern processing. A blue whale which in the early days was worth only $40 to $50 for its blubber is now worth $4,000 in Japan because of its many by-products.

LABORATORY TESTS OF WOOD PRESERVATIVES

By JOHN LEUTRITZ

BELL TELEPHONE LABORATORIES, NEW YORK

EVERY year approximately a half million new poles of southern yellow pine are used in the Bell System either for replacements or for new lines. If these poles were left unprotected from the action of lower forms of plant and animal life—fungi and termites—the economic loss would be serious. Their life can be greatly extended, however, by treating the poles with a suitable preservative. There are many preservatives on the market, and new ones are being offered from time to time to pole manufacturers, so that techniques for evaluating them must be available. Outdoor exposure tests of wood preservatives are usually slow and expensive, and it is necessary to supplement such studies with quick and inexpensive laboratory methods.

Recent experimentation has evolved an improved laboratory test which is simple and adaptable and yet gives reproducible results which are consistent with field trials of the same material. Briefly, it involves the impregnation of small pieces or blocks of wood with the preservative to be tested, and their exposure in separate glass jars to the action of different fungi. After several weeks, the preservative's effectiveness is rated by the amount and density of the fungus growth, the decrease of weight of the samples and their loss of mechanical strength.

The blocks used in testing preservatives are from the sapwood of southern yellow pine, of uniform density and rate of growth, cut usually into cubes, two centimeters on a side. Since the moisture content of the wood varies over a wide range, depending on the relative atmospheric humidity to which it has been exposed, the blocks have to be brought to a definite humidity content before each weighing at the various stages of the test. For this purpose there is used an ordinary bacteriological incubator fitted with slow-moving fans and pans of saturated solution of sodium chloride. It maintains a relative humidity of 76 per cent. at 30° C. which gives the blocks a moisture content of about 14.1 per cent. when compared with the oven-dry state.

The procedure usually followed in studying a new preservative is to inject blocks conditioned as above, with a solution of the preservative. The pieces are weighed immediately after impregnation to determine the amount of preservative injected, and after evaporation of the solvent they are reweighed under the standard conditions, referred to above, to serve as a further check on their actual content of preservative. This is of extreme importance in working with volatile preservatives.

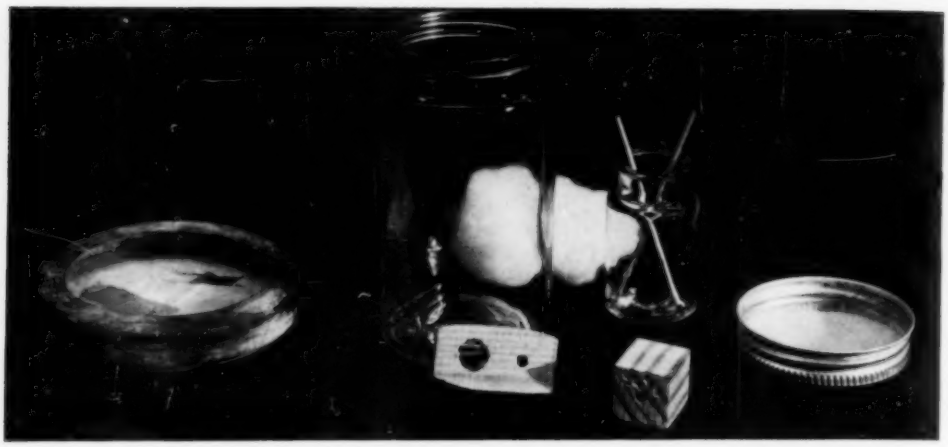
Each impregnated block is supported by a thin slab of untreated wood on the top of a small wide-mouthed bottle which contains water. The slab also acts as a secondary food source for the growth of the fungus. Wooden surgical-applicators, cut in half, are used to anchor the wood and to serve as wicks for conducting water through the test pieces. For protection the small bottles are wrapped in cotton and placed in larger bottles with screw caps. The complete set-up is sterilized for fifteen minutes at fifteen pounds pressure and then cooled to room temperature. Then a small section, cut from

INCUBATION ROOM WHERE THE BOTTLES ARE STORED DURING THE 24-WEEK TEST PERIOD AT A CONSTANT TEMPERATURE OF 26° C.

a pure culture of a wood-destroying fungus, is placed on the untreated slab of wood opposite the test specimen. The bottles are kept in an incubation room, and observed every four weeks for the extent of the fungus growth. After an exposure to the fungus of about 24 weeks, the blocks are again brought to equilibrium in the humidity chamber and weighed. The loss in weight so determined serves as one of the indications of the efficacy of the preservative.

At the present time some six hundred species of fungi are known to attack wood, and since all can not be used in each test for preservatives care must be exercised to select representative fungi. Previous experience has shown that in addition to extreme variability in virulence to different species of wood the fungi display marked idiosynerasies towards various preservatives. On the basis of these two factors many of the fungi chosen have been found in southern pine telephone poles which had failed in service.

One of these, the fungus, *Lentinus lepideus*, has been repeatedly found on



COMPONENT PARTS OF THE APPARATUS USED FOR THE WOOD-BLOCK ASSAY OF PRESERVATIVE MATERIALS.

test specimens in the laboratories' test "garden" at Gulfport, Miss., and on poles in widely separated areas in the United States. It possesses a marked resistance to certain organic preservatives, and is mentioned by several investigators as being of wide-spread economic importance in the decay of building and structural timbers. Another fungus, *Lenzites trabea*, also exerts a strong resistance to organic preservatives, but since the type of decay produced is unique in that it takes place primarily at the surface, this fungus is also included in most tests. The resistance of *Fomes roseus* varies greatly, but this flat-growing and innocent looking fungus masks an occasional virulence which makes it an essential member of every test.

Another organism included in all tests has not been identified as yet, despite attempts by several mycological authorities. It masquerades under the designation U–10. Isolated a few years ago from

TEST OF A PRESERVATIVE WITH THE WOOD-BLOCK METHOD SHOWING THE EFFECT OF INCREASING CONCENTRATION ON THE GROWTH OF THE TEST FUNGUS *Lenzites trabea*. GROWTH RATINGS FROM LEFT TO RIGHT ARE 4–4, 4–3, 3–2, 0–0.

a decayed pine telephone pole, it is especially valuable when a quick indication of the value of a new preservative is needed, as it is capable of producing a very appreciable weight loss in about three months. When preservatives of the inorganic type are under consideration common dry-rot fungi are used because of their specific resistance to this particular class of compounds. From time to time other wood-destroying organisms have supplemented those in regular use.

To aid in interpreting the results of tests on the efficacy of a preservative, second the intensity and vigor of the growth. Based on 4 as the maximum, 2–4 would mean that the block was partly covered with normal growth and 4–2 wholly covered with sparse growth. A second measure is the weight loss computed from the equilibrium weights before and after exposure to the fungus, with corrections for leaching, volatility or other causes as manifested in the uninoculated but treated test-blocks. The third basis for judging the merits of the preservative is the dissection or strength rating determined by breaking the blocks

GROWTH ON UNTREATED SOUTHERN PINE SAPWOOD OF THE FOUR ORGANISMS USED NORMALLY IN EVERY TEST. THE FUNGI FROM LEFT TO RIGHT ARE *Lenzites trabea, Lentinus lepideus, Fomes roseus,* AND AN UNIDENTIFIED SPECIES (U-10) ISOLATED FROM A SOUTHERN PINE POLE WHICH FAILED IN SERVICE. THE SPECIMENS WERE REMOVED FROM THE LARGE BOTTLES FOR PHOTOGRAPHING.

untreated controls are also exposed to the different test fungi; and treated controls are put through the entire test cycle without inoculation. These controls are valuable indicators of the nature of the preservative from the standpoint of solubility, volatility and chemical stability; and particularly of the strength lost by the exposed blocks.

Three criteria are available as measures of the value of a preservative. First there is the growth rating which is made every four weeks with reference to the untreated norm. This rating is designated by a pair of numbers, the first of which indicates the extent of the test block covered with the fungus, and the in small pieces and comparing them with the uninoculated controls treated in a similar manner.

This modification of previous wood-block test methods is no doubt capable of still further development, but several years' experience with it has provided case histories for many preservatives which show a gratifying correlation between results of this accelerated and inexpensive laboratory test and of the slower and more expensive field trials. The severity of the method may in some cases be criticized, but this very severity is essential in the elimination of the poor and mediocre materials unworthy of further study.

THE LEIDY MEDAL OF THE AMERICAN ASSOCIATION OF ANATOMISTS

THE PROGRESS OF SCIENCE

THE ANATOMISTS' ANNIVERSARY MEDAL

FIFTY years ago a group of men interested in anatomy met in Washington, D. C., and founded the American Association of Anatomists. Joseph Leidy, professor of anatomy at the University of Pennsylvania, was chosen president. This year the association celebrated the fiftieth anniversary of its founding, at the annual meeting held at the University of Pittsburgh from April 14 to 16. In connection with the celebration, portrait medals of Leidy were struck, as shown in the accompanying photographs. The face of the medal shows in bold relief a profile view of the head of Professor Leidy, and around the edge is the inscription—Joseph Leidy, 1823–91, 1st president, American Association of Anatomists, 1888–91. On the back in island relief are the words "To celebrate fifty years of achievement," and beneath is a spray of laurel. The medals are of bronze, two and a half inches in diameter.

The designs for the medal were made by Dr. R. Tait McKenzie, who from 1896 to 1904 was demonstrator of anatomy at McGill University, and during that period was a member of the American Association of Anatomists. In 1904 Dr. McKenzie became professor of physical education at Pennsylvania. He then divided his time between his professional duties and sculpture, and in the latter field he won renown for his statues of athletes in action and his war memorials. The association was especially fortunate in having one of its former members also a distinguished sculptor, who could do justice to the subject. Dr. McKenzie took up the idea with enthusiasm. As a basis for Leidy's head he used a portrait by Daniel Huntington, painted in middle life, and a Gutekunst photograph, taken at a later period. These he has combined in a harmonious way to produce a head of great dignity and power.

The suggestion of striking a medal bearing the likeness of Professor Leidy came from Professor Frederic T. Lewis, president of the association, and was at once accepted as befitting the occasion. A committee was formed in Philadelphia to arrange for the medal. The committee consisted of Professor Charles W. Burr, a former student and great admirer of Leidy, Henry H. Donaldson and William H. F. Addison. To the committee were later added John C. Donaldson, of the University of Pittsburgh, and Edmond J. Farris, of the Wistar Institute of Anatomy. The committee suffered a great loss by the death of Professor Henry H. Donaldson, who died in January of this year, and recently all have been shocked by the death of Dr. McKenzie. The Leidy medal is, perhaps, the last work that he completed. Undoubtedly it will be more highly prized as the years pass.

Leidy is everywhere recognized as one of America's foremost scientists, and his selection as first president was of great value to the young society. Franklin P. Mall, in his presidential address to the association in December, 1906, said of Leidy: "The greatest of this brilliant group was Leidy, in fact he was the greatest teacher of anatomy to medical students this country has ever seen. His ideals were of the highest and his scientific discoveries were numerous and accurate, contributing much to comparative anatomy and zoology. The good influence he exerted upon the various institutions in Philadelphia has been extended over the nation through this association, of which he was one of the founders."

Professor George A. Piersol, Leidy's successor in the chair of anatomy, had the greatest admiration for Leidy's textbook, "An Elementary Treatise on

Human Anatomy" (1861) and considered it the clearest and most straightforward presentation of the subject possible for the beginning student. Leidy also edited an American edition of Quain's "Anatomy," which was published in 1849. Leidy's connection with the teaching of anatomy began at his graduation in 1844, when he became an assistant in the dissecting room. The next year he was appointed prosector to Professor Horner, and in 1854 succeeded him as professor of anatomy.

"He knew how to use his anatomical opportunities," declared Charles Sedgwick Minot, who admired him, "a Philadelphian by his birth, by his career, and by his death, and no citizen of this metropolis has more deserved public honor than he." Yet his interests were unconfined by any narrow discipline. He searched all sorts of animals, finding material for 597 listed publications, among them "classics of American science." Fundamental studies in vertebrate paleontology, the splendid monograph on rhizopods, the discovery of encysted trichina in pork, the transplantation of cancer cells to the frog, and researches on the comparative histology of the liver and the intimate structure of cartilage in 1848 and 1849, are among those readily recalled. Clear vision, perfect modesty, noble and unflagging devotion to science are qualities to commemorate. These are Leidy's traits, which the sculptor has admirably portrayed in this notable anniversary medal.

WILLIAM H. F. ADDISON
UNIVERSITY OF PENNSYLVANIA

THE ANNUAL MEETING OF THE NATIONAL ACADEMY OF SCIENCES

THE seventy-fifth annual meeting of the National Academy of Sciences was held on April 25, 26 and 27, 1938, at the academy building on Constitution Avenue in Washington, with a hundred and twenty-four members in attendance. The scientific sessions were unusually interesting; thirty-two papers were read; although these were of necessity somewhat technical in character, each speaker made a sincere effort to present the general results of his research work and to emphasize their significance rather than to discuss details understandable only to the specialist in that field. Experience has proved that it is not an easy task to prepare a paper for presentation before the general scientific audience of the academy. The excellence of the papers given at the recent sessions showed clearly that this difficulty was realized.

The distribution of the papers among the different fields of science was: astronomy 3, mathematics 4, physics 8, chemistry 2, geology 1, geography 1, paleontology 1, biophysics 5, biology 1, botany 1, physiology 1, pathology 1, psychology 2 and anthropology 1. Twenty-four papers were given by members of the academy and eight by scientists introduced by members. The Monday evening public lecture was delivered by Dr. James Ewing, of Memorial Hospital in New York City, on the subject "The Public and the Cancer Problem." His illuminating and authoritative address on the present status of cancer research and on the relation of the public to it was closely followed and greatly appreciated by the audience eager to learn of the many factors that enter into this difficult problem.

The large number of reports from the field of physics indicated the continued interest in this fruitful branch of science. Dr. R. W. Wood reported upon new large diffraction gratings, ruled on aluminized pyrex blanks, by which 75 per cent. of the incident light of the visible spectrum is concentrated in the second order spectrum; by another grating, 85 per cent. of yellow light is concentrated in the first order spectrum. Drs. W. W. Coblentz and R. Stair described a new method that utilizes unmanned balloons for exploring

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radiometrically the ultra-violet solar intensities in the stratosphere, thereby obtaining information on the distribution of ozone in the atmosphere to a height of 19 kilometers. Drs. I. S. Bowen, R. A. Millikan and H. V. Neher presented new evidence on the nature and origin of incoming cosmic rays. Dr. H. E. Ives reported upon the results of an experimental study of the rate of a moving atomic clock as furnished by the Doppler effect in canal rays whose velocities can be accurately controlled by use of the Dempster canal-ray tube. In the tube a small concave mirror was inserted so that the end-on observation gave, on one plate in the spectrograph, the displaced spectral lines due to motion toward and away from the spectrograph slit. On the assumption of a stagnant ether, this experiment establishes the physical reality of the Larmor-Lorentz variation of clock rate and the Fitzgerald contraction. Dr. E. Kasner outlined a new method of approach to the geometry of motions and whirls. Drs. O. L. Inman and A. F. Blakeslee described the absorption spectrum of a new type of chlorophyll resulting from a recessive palemutation in the jimson weed (*Datura stramonium*). Drs. H. C. Urey, H. G. Thode and G. E. Gorhan reported upon a new method for the concentration of isotopes of nitrogen and sulfur by chemical means. Drs. R. D. Evans and R. S. Harris described the metabolic effects of ingested radium in rats; this leads ultimately to the production of osteogenic sarcoma. Drs. W. J. V. Osterhout and J. W. Murray described experiments on the movement of water from concentrated to dilute solutions through liquid membranes, a new phenomenon difficult to explain. Dr. H. Fletcher reviewed experiments on the relation of the intensity per cycle of acoustical noise to the intensity of a pure tone of given frequency and just perceptible against the background of noise; he also showed how it is possible, from measurements of this ratio

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with change in frequency, to compute the relation between the frequency of the tone and its position of maximum stimulation along the basilar membrane. Dr. W. B. Scott presented the results of studies on members of the camel family existent in North America and nowhere else during the Tertiary period. Toward the end of this period they migrated to South America and to Asia and are no longer found wild in North America.

In his address before the academy at its annual dinner President Lillie alluded in detail to the fiftieth anniversary of the academy in 1913 at which a number of remarkable addresses were given by scientists and high government officials from this country and abroad. He referred briefly to the activities of the academy during the world war as scientific adviser to the government, to the organization of the National Research Council by the academy in 1916 and to its major activities during the past 19 years since the war. He mentioned with special pleasure the Pilgrim Trust Lectureships initiated by the Royal Society and recently established through agreement between the Royal Society of London and the National Academy of Sciences, whereby for a period of six years a Pilgrim Trust lecturer is to be chosen annually. The first lecturer is to be an American scientist appointed by the Royal Society to give a lecture before the Royal Society; the second lecturer is to be a British scientist appointed by the academy to give a lecture the following year before the Academy in Washington. The Royal Society has appointed Dr. Irving Langmuir, member of the academy, to give the first Pilgrim Trust Lecture in December of this year in London.

Two gold medals, awarded by the academy on April 28, 1937, were presented at the annual dinner.

The Agassiz Medal for oceanography, awarded to Edgar Johnson Allen, director emeritus of the Plymouth Laboratory of the Marine Biological Association of

the United Kingdom, Plymouth, England, "in recognition of his personal researches on marine biology and of the great influence which he has exerted on the study of marine organisms in their relation to the marine environment." The presentation address was made by Dr. E. G. Conklin, member of the committee that made the award. The medal was received, on behalf of Dr. Allen by Mr. Leander McCormick-Goodhart of the British Embassy for transmission to Dr. Allen through diplomatic channels.

The Public Welfare medal from the Marcellus Hartley Fund was awarded to Willis Rodney Whitney, of the General Electric Company research laboratories, "in recognition of his outstanding work in the fundamentals of scientific research for the public good." The presentation address was made by Dr. A. W. Hull, chairman of the committee that recommended the award.

At the business meeting held on Wednesday, April 27, the following officers and members were elected:

New members of the council:

F. K. Richtmyer, Cornell University

E. D. Merrill, Arnold Arboretum, Harvard University

New foreign associates of the academy:

Alfred Fowler, professor of astrophysics, University of London

Pierre Janet, professor of psychology, Collège de France

S. P. L. Sørensen, director of the chemical division of the Carlsberg Laboratory, Copenhagen

D. M. S. Watson, Jodrell professor of zoology and comparative anatomy, University College, London

New members of the academy:

Carl David Anderson, California Institute of Technology

Walter Hermann Bucher, University of Cincinnati

Edward Adelberg Doisy, St. Louis University, Missouri

John Adam Fleming, Department of Terrestrial Magnetism, Carnegie Institution of Washington

Theodore von Kármán, California Institute of Technology

Warren Kendall Lewis, Massachusetts Institute of Technology

William deBerniere MacNider, University of North Carolina

Carl Shipp Marvel, University of Illinois

Theophilus Shickel Painter, University of Texas

Worth Huff Rodebush, University of Illinois

Lewis John Stadler, University of Missouri

George Walter Stewart, University of Iowa

Marshall Harvey Stone, Harvard University

Louis Leon Thurstone, University of Chicago

Simeon Burt Wolbach, Harvard Medical School

The present membership of the academy is 303, with a membership limit of 350; the number of foreign associates is 40 with a limit of 50.

The autumn meeting will be held this year on October 24, 25 and 26 at the University of North Carolina.

F. E. WRIGHT,
Home Secretary.

SCIENCE AND THE NEW YORK WORLD'S FAIR

"To tell the whole story of modern scientific research instead of a single chapter—as far as practical, to add a working, scientific display to every major exhibit."

This was the difficult ideal set for the New York World's Fair 1939 by Grover A. Whalen, president of the Fair Corporation. And it is an ideal that will come amazingly close to complete realization. Instead of divorcing science from life and isolating it in a separate hall, the exposition will attempt to show the relationship of science to the industries and occupations of daily existence by which men gain their bread and butter.

To carry out this plan, Mr. Whalen recently announced the appointment of Dr. Gerald Wendt, director of the American Institute of the City of New York, to draw up a plan of encouraging and coordinating scientific displays. Even before the appointment of Dr. Wendt,

MODEL OF THE NEW YORK WORLD'S FAIR

THE PICTURE SHOWS THE CENTRAL THIRD OF THE 1,216½ ACRE SITE, INCLUDING THE MAIN EXHIBIT AREA, THE GOVERNMENT AREA (UPPER LEFT) AND A SEGMENT OF THE AMUSEMENT AREA (UPPER RIGHT). THE MOST CONSPICUOUS STRUCTURES ARE THE 18-STORY PERISPHERE AND 700-FOOT TRYLON AT THE THEME CENTER.

however, much progress had been made in this direction.

Innumerable examples could be cited—as, for example, the building of a model town to demonstrate all that traffic engineers and architects and manufacturers and construction engineers have done to make possible a comfortable and gracious way of living. Or the demonstrations of how new industries grow out of abstract scientific research, as will be done by the Radio Corporation of America in the first exhibit of practical television.

One of the most interesting scientific exhibits, however, will be the one telling

THE HALL OF MEDICINE AND PUBLIC HEALTH

THE BUILDING WILL BE LOCATED ON THE THEME PLAZA OF THE FAIR AND WILL COST ABOUT $425,000. AMONG THE EXHIBITS WILL BE MODELS OF VARIOUS PARTS OF THE HUMAN BODY LARGE ENOUGH TO PERMIT VISITORS TO ENTER THEM AND BECOME INTIMATELY ACQUAINTED WITH THEIR MECHANISMS.

of the age-long struggle of science against disease and mortality.

"This is not to be an exhibit for doctors," said Mr. Whalen in announcing a committee of eminent physicians appointed to develop the display. "It is an exhibit, however, in which the medical profession surely will be deeply interested. We want to have the subject of medicine and public health brought to the consciousness of the average man. We want him to realize what is available to him in both knowledge and technique, to appreciate dangers and the means of avoiding them in his home life and elsewhere."

For the first time in any international exposition, a large separate building—now nearing completion—is devoted to medicine and public health. The building is divided into three main chambers of great size—the Hall of Man, the Hall of Medical Science and the Hall of Public Health.

The Hall of Man, its interior cathedral-like in design, is to dominate the building. The sound of a low, measured pulsation permeating this vast chamber will be discovered to be the heartbeat of an imposing 18-foot statue of a man standing at one end of the hall. This model, transparent, yet accurate in every particular, will disclose the intricate workings of every organ with which nature has endowed the adult human body.

Surrounding this giant figure, other transparent models will show the processes of respiration and digestion, the action of eye and ear and brain, the mysteries of growth and reproduction.

In the Hall of Medical Science, a series of lifelike dioramas will tell the whole story of the healing art from its crude

AND 700-FOOT TRYLON AT THE THEME CENTER.

beginnings in imitative magic and the incantations of witchmen. One exhibit will show a marketplace of ancient Babylon or Nineveh, with a sick man carried in by his friends to seek the help of any casual passerby.

Another will show the barber-surgeon of the Middle Ages, with his crude unsterilized instruments, ready to shave the patient, extract a tooth or bleed him, all with equal assurance.

Contrasted with this group will be the entire story of modern hospitalization with a staff of chemists, bacteriologists and biologists, behind the scenes in laboratories, perhaps never seeing the patient, but bringing all the resources of science to accurate diagnosis and treatment. Every step in the process of hospitalization will be shown—admission of the patient, diagnosis, nursing care, the operating room with its extraordinary precautions against infection, convalescence and final discharge of the cured patient.

Equally complete will be the exhibits in the Hall of Public Health, where the story of home and municipal sanitation with kindred topics will be presented in a dramatic fashion that entertains while it educates. Here will be a series of exhibits exploding popular yet harmful superstitions. Even the scientist whose specialized activities lie in other directions may find here much that is as surprizing as it is informative.

Similar exhibits will mark other sections of the fair. In the transportation section, for example, will be exhibits telling in pictorial form the entire story of man's search for rapid, comfortable, safe means of travel. Another will tell the progress of aviation, showing all the scientific steps by which safety in the air has been achieved. This will include a complete demonstration of instrument or "blind" flying, showing the means by which the pilot whose vision is obscured by cloud or mist or snow can take off, navigate and land with little if any more trouble than in clear weather.

In a sense, the construction of the New York World's Fair itself is an almost melodramatic demonstration of scientific achievement.

For two centuries, most of the 1,216½-acre site in Flushing Meadow Park was regarded as a useless tidal marsh. On a part of this marsh had been dumped over a period of many years 50,000,000 cubic yards of ashes and refuse. It seemed a difficult enough undertaking to transform this waste land into a sightly park—to say nothing of creating there a magic city with an average population of 300,000 inhabitants.

The first step was to take borings over the entire site—many of them as deep as 100 feet—to find the exact depth to which piling would have to be driven. This task was completed before the first steps of construction were taken.

The entire surface had to be graded. Almost 7,000,000 yards of ash fill and meadow mat had to be moved and redistributed. Topsoil had to be created from these crude materials by the aid of chemical engineers. All these immense undertakings were achieved.

Now, a year before the opening date of April 30, 1939, more than thirty-five buildings are in an advanced state of construction, seven are completed, thousands of trees up to 50 feet tall have been planted, and construction is well advanced on 17 miles of roads and 34 miles of walks. Approximately $10,000,000 has disappeared below ground in such vital improvements as electric wiring, sewers and drains, water mains and telephone cables.

The total cost of the fair will be approximately $150,000,000. The Federal Government, 37 states and 64 foreign governments have taken steps toward active participation. Total attendance at the fair is expected to be 50,000,000. Average daily attendance is calculated at 250,000, with as many as 800,000 on special occasions.

CORRESPONDENT

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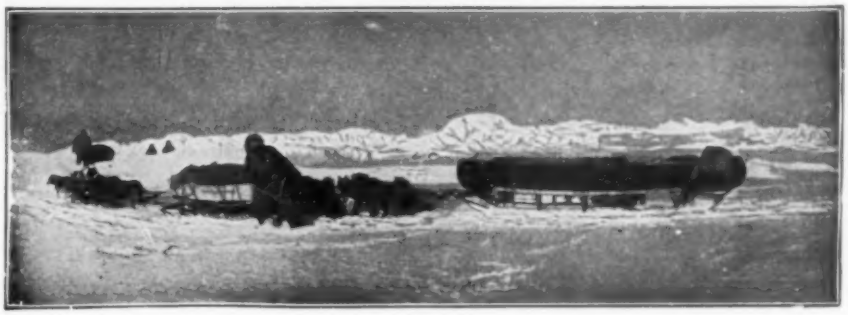

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